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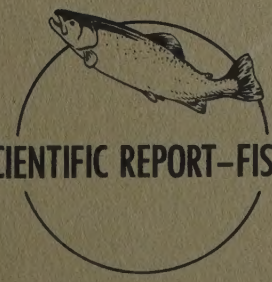

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The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. it is issued in limited quantities for official use of Federal, State or cooperating agencies and in processed form for economy and to avoid delay in publication

United States Department of the Interior, Douglas McKay, Secretary
Fish and Wildlife Service, John L. Farley, Director

COMMERCIAL FISHERY FOR CHUBS (CISCOES) IN LAKE MICHIGAN THROUGH 1953

By

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ABSTRACT

The chub fishery of Lake Michigan is based on 7 deep-water species of coregonines. Small-mesh gill nets are the principal means of capture, and almost the entire production enters the smoked-fish trade. Statistics before 1926 were incomplete and scattered but are sufficient to indicate that the annual catch sometimes ran into millions of pounds as early as the 1890's. The take in 1926-1953 ranged from 1,630,000 pounds in 1941 to 11,151,000 pounds in 1953. Percentages contributed by the states averaged: Wisconsin 60.4; Michigan 22.9; Illinois 14.0; Indiana 2.7. The catch increased annually from 1941 to 1953.

Statistics on production, fishing intensity, and catch per unit effort for Michigan (1929-1953), Illinois (1950-1953), and Wisconsin (1953) are used for the description of fluctuations and for comparisons of local areas (statistical districts). Trends of fishing intensity and availability, as well as of take were strongly upward in most State of Michigan districts, and probably in Illinois and Wisconsin as well, from the early 1940's through 1953.

Three factors make for a progressive deterioration in the quality of chubs available to Lake Michigan fishermen: a rise in fishing intensity brought about by the diversion to chubs of fishing pressure formerly directed against lake trout; an increase in the abundance of the largely unsalable bloater which followed the disappearance of the predatory trout; the selective destruction of the larger chubs by the sea lamprey. The presently difficult situation of the chub fishery threatens to become critical.

Statistics for 1954 are given in an appendix.

CONTENTS

	Page
Material and methods	4
Production of chubs in Lake Michigan by state, 1890-1953	4
Production in 1890-1925	4
Production in 1926-1953	7
Production of chubs in statistical districts, 1929-1953	12
State of Michigan, 1929-1953	12
State of Wisconsin, 1953	23
Abundance of chubs in Lake Michigan, 1929-1953	23
State of Michigan, 1929-1953	26
States of Illinois, 1950-1953, and Wisconsin, 1953	32
Intensity of chub fishery in Lake Michigan, 1929-1953	34
State of Michigan, 1929-1953	34
States of Illinois, 1950-1953, and Wisconsin, 1953	43
Summary	43
Literature cited	45
Appendix: Lake Michigan chub fishery in 1954	46

COMMERCIAL FISHERY FOR CHUBS (CISCOES) IN LAKE MICHIGAN THROUGH 1953

An historical account of the commercial fishery for chubs is beset with numerous difficulties, many of which stem from the composite nature of the fishery. In Lake Michigan the production of chubs has included catches of seven different species of the sub-genus Leucichthys of the genus Coregonus as follows 1/:

Deepwater cisco	C. johannae
Longjaw cisco	C. alpenae
Shortjaw cisco	C. zenithicus
Shortnose cisco	C. reighardi
Blackfin cisco	C. nigripinnis
Kiyi	C. kiyi
Bloater	C. hoyi

The resemblances of these species to each other, of all of them to the closely related lake herring (C. (Leucichthys) artedii), and the superficial similarities of large chubs to lake whitefish (C. (Coregonus) clupeaformis) and round whitefish (C. (Prosopium) cylindraceus) led to much confusion in the earlier statistics. In a number of years part or all of the catch of chubs was combined with lake whitefish and round whitefish or with lake herring. (See later section on production in 1890-1926 for details on problems of chub statistics.) Usable statistics on the production of chubs in Lake Michigan start with 1926, in which year the U. S. Bureau of Fisheries (now part of the Fish and Wildlife Service) introduced the category "chubs" (all species of the subgenus Leucichthys except lake herring) and published the first records of take ever issued for Indiana and Illinois.

Even if we had complete records of chub production from the earliest days of the fishery, their value would be limited by the long-term changes in the species composition of the catch--changes that we know to have taken place, and to be continuing now, even though we are largely without data to describe them quantitatively. Much of the uncertainty as to the species in the catch arose from the lack of adequate taxonomic descriptions of the species 2/ as well as from a great local diversity of common names.

The early fishery for chubs was based principally on blackfins and longjaws and was carried on with gill nets of mesh sizes mostly greater than 3 inches, extension measure. As to the identity of the blackfin of this early fishery, there is little question. Smith and Snell (1891) were doubtless correct when they termed it C. nigripinnis. 3/ Their designation of longjaws as C. tullibee, on the contrary, leaves room for question as to the identity of the fish. (Koelz, 1929, considered tullibee a synonym of artedii; in 1931 he listed tullibee as a subspecies of artedii.) The longjaw of current systematics (alpenae) was not described by Koelz until 1924. Furthermore, this common name may have been applied to different species in different localities. In Lake Superior, for example, fishermen today apply longjaw to zenithicus; a similar designation may have been used by some fishermen on Lake Michigan. Although the longjaws of the early fishery may have included some alpenae and some zenithicus, it is strongly probable that a good proportion of them were johannae, a species that shares the blackfin's preference for deep water (mostly below 50 fathoms) and one that attains considerable size.

1/ Many North American workers recognize the three types of coregonines present in the Great Lakes as belonging to the separate genera, Coregonus, Leucichthys, and Prosopium. The common names given here are those approved by the American Fisheries Society. Later in this paper, however, we shall use "chub" rather than "cisco" since the former term is employed uniformly throughout the fishing industry of Lake Michigan.

2/ A sound taxonomy of Lake Michigan chubs was first established with the publication of Koelz' (1929) monograph.

3/ Smith and Snell apparently were deceived by local usage when they mentioned the production of large quantities of backfins in Green Bay near Escanaba. The term bluefin, often used synonymously with blackfin, also is commonly applied to lake herring in Green Bay.

As the abundance of the large chubs of the early fishery declined under commercial exploitation, mesh sizes were decreased to maintain the catch and smaller species became more important in the fishery. According to Koelz (1926), 2-3/4 inch mesh came into general use in the 1890's and by 1910 Wisconsin and Illinois fishermen had reduced the mesh size to 2-1/2 inches. In Michigan, however, the minimum legal mesh size continued at 2-3/4 inches until 1933. Further comments on recent changes of mesh regulations are given in a later discussion of fluctuations in the catch per unit effort.

For many years now, the chub fishery has depended on five medium- and small-sized species, namely, alpenae, zenithicus, reighardi, kiyi, and hoyi. Both blackfins and deepwater cisco were relatively scarce (and probably had been for years) at the time of the 1930-1932 investigations of the Bureau of Fisheries vessel Fulmar [4/] and have continued scarce through to the present time.[5/] Several species are regularly taken in a single-lift of gill nets, but if the fish can be located in sufficient abundance, fishermen prefer alpenae and zenithicus which are larger than the other three species and are of better quality for smoking. (Practically all chubs are smoked.) Only the largest of the slowly growing bloaters are marketed. Kiyis and shortnose chubs are more acceptable than bloaters but still fall short of top quality. The habits of fishermen, of course, vary with locality, time of year, and from year to year according to availability of the several species and the market's acceptance of different kinds and sizes of fish.

4/ See Deason (1932) for an account of the purpose of the investigations and Van Oosten (1933) for a preliminary statement of findings on the abundance of chubs and small lake trout (Salvelinus namaycush). Materials collected from the Fulmar were the principal basis of studies on the distribution, abundance, and growth of reighardi (Jobes, 1943), hoyi (Jobes, 1949a), alpenae (Jobes, 1949b), and kiyi (Deason and Hile, 1947; Hile and Deason, 1947).

5/ A modest but short-lived recovery of blackfins took place, especially in the Sheboygan-Manistee-Ludington regions, in the 1940's. The peak probably occured in 1944 and 1945.

Although the long-term trends in species and size composition of Lake Michigan chubs forced changes in fishing methods and were marked by a gradual deterioration in the quality of the catch, the industry adjusted well to new conditions and continued productive, if not always prosperous. Within recent years, however, population changes have been taking place which threaten the very existence of the chub-fishing industry. These changes can be explained as direct and indirect consequences of the rapid expansion of the sea lamprey population in Lake Michigan.

The story of the sea lamprey's penetration of the upper Great Lakes and of that parasite's rapid spread and destruction of the lake trout stocks has been too well documented to need repetition here (Van Oosten, 1949; Moffett, 1950; Applegate, 1951; Applegate and Moffett, 1955; and others). The destruction of lake trout was particularly rapid in Lake Michigan where the annual catch dropped from 6,498,000 pounds in 1944 to 342,000 pounds in 1949 (Hile, Eschmeyer, and Lunger, 1951a) and where the 1953 production was less than 500 pounds. The decline and disappearance of trout upset radically the ecology of the fish population in the deeper waters of the lake.

The ecological situation in the deeper waters of Lake Michigan prior to the invasion of the sea lamprey was relatively simple and moderately stable. Most plentiful small- and medium-sized fishes were various cottids and the seven species of chubs. The major predator on these fishes was the lake trout; the burbot (Lota lota), which disappeared along with the trout, inhabited deep water but it was far less abundant than trout and had somewhat less predatory habits. According to Van Oosten and Deason (1938), smaller lake trout consumed mostly invertebrates and cottids (also sticklebacks, Pungitius pungitius, toward the north), but among trout above 15 inches coregonids became strongly predominant in the diet. The bloater, smallest and commercially least valuable of the chubs, held first rank as food for the larger trout. Just what the annual consumption of bloaters may have been when lake trout were plentiful is a matter for speculation but best judgment suggests that the amount must have been enormous. If, for example, we assume

that 5 pounds of bloaters are required to produce 1 pound of lake trout we arrive at a figure of 30 million pounds of bloaters per year to produce the average annual commercial take of roughly 6 million pounds of trout in the years preceding the collapse of the lake trout fishery. To be sure, lake trout did not feed exclusively on bloaters. On the other hand, by no means were all lake trout taken commercially--some met natural death. The estimate of an annual consumption of 30 million pounds of bloaters by the lake trout, therefore, is held to be minimal; it is probably far too low.

The bloater was well adjusted to this heavy predation by lake trout. It maintained a level of abundance that not only was adequate to the needs of trout but was also on occasion displeasing to fishermen who had to clear their nets of large numbers of unsalable bloaters that had become entangled by their mouth parts and fins. Relieved from predation by lake trout, bloaters multiplied rapidly, offering more valuable chubs unaccustomed competition for food and space, and creating a nuisance to commercial fishermen.

Increased competition from bloaters is only one of three major factors operating against the welfare of the commercially useful chubs. Second is a greatly heightened fishing pressure. When the lake trout disappeared, most Lake Michigan fishermen outside Green Bay had to choose among retirement from fishing, moving to other waters, or directing their fishing operations primarily toward the production of chubs. A few did stop fishing and a few did move, but the large majority are still active in Lake Michigan.

The third factor, and one probably far more damaging to chubs than increased fishing pressure, is destruction by sea lampreys. According to Applegate (1950) the recently transformed sea lampreys, which enter the lake at an average length of about 5-1/2 inches to begin their parasitic existence, move to deep water and remain there through much of the summer. Whether these young lampreys exercised any selection between lake trout and chubs during their early feeding is not known, but growth soon carried the lampreys to a size where mechanics of attachment alone would make them more likely to attack trout than fish as small as most chubs. Applegate's measurements of sea lampreys from Lake Huron showed average lengths of roughly 10 to 10-1/2 inches in July, more than 12-1/2 inches in August, and more than 13-1/2 inches in September. Thus the lampreys complete a considerable amount of growth by September in which month they appear to be entering the inshore waters.

We do not have data for Lake Michigan corresponding to those published by Applegate for Lake Huron, but the general situation seems to be similar--that is, sea lampreys tend to remain in deep water during the summer but become common inshore in the fall. At present, however, Lake Michigan has almost no lake trout on which lampreys can feed during their deep-water residence. They must subsist on chubs alone, and the lamprey soon reaches a size that forces it to select the larger chubs. This selective destruction can be expected to continue as long as Lake Michigan supports a large stock of sea lampreys.

Because of the deterioration of the Lake Michigan chub stock which has made fishing difficult and threatens to lead to critical conditions, the Fish and Wildlife Service in 1954 started a fishery-limnological program on the lake. Major goals of the study are: determination of species, size, and other characteristics of the present chub stock, including a comparison with conditions at the time of the 1930-1932 Fulmar investigations; survey of limnological conditions in relation to movements and distribution of fish, availability of and competition for food, ...; testing of various types of sampling gear, including the possible development of means for the large-scale production of bloaters at a cost which would permit their utilization for purposes not now economically feasible.

The present paper is intended to contribute to the Lake Michigan program by making readily accessible the available statistics on the chub fishery.

James W. Moffett, Chief, Great Lakes Fishery Investigations, John Van Oosten, and Stanford H. Smith read the original draft of the

manuscript. Dr. Van Oosten also supplied information on problems of legislation and law enforcement in the early 1930's. The figures were prepared by William L. Cristanelli.

Materials and methods

Records of chub production by state through 1940 have been adapted from Gallagher and Van Oosten (1943). Statistics on production after 1940 were compiled in the Ann Arbor offices of the Fish and Wildlife Service (Michigan in all years; Indiana and Illinois after 1949; Wisconsin in 1953) or supplied by State conservation agencies (Indiana and Illinois through 1949; Wisconsin through 1952).

All compilations of production records and estimates of abundance (availability) and fishing pressure in statistical districts were made in Ann Arbor from monthly fishing reports submitted to the states by every licensed commercial fisherman and later turned over to the Service for analysis. Each of these reports carries a daily record of the kind and amount of gear lifted and of the catch in pounds of each species (group of species for chubs). Methods employed for the analysis of commercial fishery statistics of the Great Lakes have been outlined in earlier papers by Hile (1937), Hile and Jobes (1941), and Van Oosten, Hile, and Jobes (1946). The actual procedure is simpler with chub statistics than for species in which the catch is taken by two or more important gears. Practically all chubs are caught in small-mesh gill nets (2-1/4 to 2-7/8 inches--legal minimum and maximum have varied with state and year). Indices of abundance accordingly have been computed from fluctuations in the catch per unit effort of that gear alone. Fishing intensity has varied almost exactly according to the amount of small-mesh gill nets lifted that contained chubs, since only small adjustments were needed to correct for production by other gears.

Production of chubs in Lake Michigan by state, 1890-1953

Production in 1890-1925.--As was stated in the introductory section, records of chub production in Lake Michigan prior to 1926 are generally unsatisfactory. No statistics are available at all for Illinois and Indiana, and many of the records for Michigan and Wisconsin are incomplete or include fish for which the species identification may be questioned. The statistics for 1890-1925 (table 1) do have some value, nevertheless, in providing minimal estimates of take. Questions concerning these data are best handled by quoting directly from Gallagher and Van Oosten (1943). In the following paragraphs, "U. S. Fisheries" refers to statistical reports of the Fish Commission and the Bureau of Fisheries, and "U. S. Census" to reports of the Bureau of the Census.

> "In Lake Michigan the larger chubs, that is, longjaws and blackfins, were included with whitefish in U. S. Fisheries reports for 1879, 1885, 1890, and 1893. In these same years the smaller species of chubs probably were included with lake herring in all lakes. It may be assumed, however, that the smaller chubs did not contribute greatly to the reported yield of lake herring in the earlier years since the really intensive exploitation of the small chubs got under way in the late 1920's particularly after the collapse of the cisco fishery of Lake Erie in 1925.
>
> "After 1890 the treatment of the statistics for chubs and lake herring in U. S. Fisheries varied widely. Part of the chubs were listed in some years as blackfins (or bluefins), longjaws, or longjaws and blackfins combined, but until the category "chubs" was introduced in 1926 all the smaller varieties presumably were grouped with lake herring. In 1917, 1922, and 1925 all chubs and lake herring were combined as "ciscoes."... .
>
> "The U. S. Census data for 1889 combined all chubs and the Menominee whitefish with lake herring. The 1908 statistics included records for bluefins or blackfins and longjaws. The

Table 1.--Production of chubs in Michigan and Wisconsin waters of Lake Michigan, 1890-1925

[In thousands of pounds; adapted from Gallagher and Van Oosten (1943); no records of catch in Illinois and Indiana before 1926; statistics from State records except as noted]

Year	Michigan	Wisconsin	Total	Year	Michigan	Wisconsin	Total
1890	...	...	1/ 1,398	1908	2,339	3/ 715	3,054
1891	36	...	...	1909	...	3,526	...
1892	...	...	...	1910	...	2,507	...
1893	...	1,476	...	1911	137	2,424	2,561
1894	...	2,500	...	1912	29	2,791	2,820
1895	...	1,600	...	1913	173	3,671	3,845
1896	...	3,000	...	1914	6	3,362	3,368
1897	...	387	...	1915	24	2,888	2,912
1898	1,849	...	...	1916	5	1,782	1,786
1899	2,212	2/ 250	2,462	1917	14	3,727	3,742
1900	2,014	...	...	1918	1,580	4,183	5,763
1901	1,464	...	...	1919	1,113	3,814	4,927
1902	1,120	...	...	1920	536	1,770	2,306
1903	931	2/ 400	1,331	1921	390	955	1,346
1904	1,620	...	...	1922	144	1,282	1,426
1905	...	...	...	1923	270	966	1,237
1906	3,848	...	...	1924	514	1,760	2,273
1907	1,912	...	...	1925	1,013	2,827	3,840

1/ Blackfins, longjaws, and round whitefish, including any of these species taken in Illinois and Indiana; data from U. S. Fish Commission

2/ From U. S. Fish Commission report

3/ From U. S. Bureau of the Census report

smaller chubs probably were included with lake herring although no statement was made to that effect.

"Scattered statistics on the production of chubs were obtained from the original State of Michigan records for 1891-1908. All of these catches were designated by marginal notations alongside figures entered in the column for lake herring. Practically all were labeled specifically as longjaws or blackfins although a few entries were indicated as chubs in the later years of the period. All these records of chub production must be held as minimal. The variation of the figures leaves little doubt that longjaws and blackfins were separated from herring in only certain years, and there is no proof that the separation was complete in any year. Furthermore, the small chubs were unaccounted for in almost all years.

"The published reports of the State of Michigan for 1911-18 contained one entry for 'longjaws' and another for 'herring or chubs'. After 1918 a satisfactory separation seems to have been made although in 1919-21 the chubs were divided into the categories 'blackfins and bluefins' and 'longjaws or chubs'.

"Usable statistics in the original records of the State of Wisconsin did not include an item 'chubs' before 1909. Before 1909 most or all chubs probably were included in the category 'bluefins'. This same group appears also to have included part of the chubs in 1909 and later years. Unfortunately the significance of the term 'bluefin' varies with locality. We believe that we have obtained the best figures possible by considering all bluefins from Lake Michigan proper and from Lake Superior to be chubs and all bluefins from Green Bay to be lake herring."

From the preceding it appears that the catches listed for Michigan were in fact chubs but that many or most of the records were incomplete. The problem of completeness of coverage exists for Wisconsin also; in addition there is some question as to the validity of the interpretation of the state records of catches of bluefins.

The Michigan statistics indicate an active chub fishery in 1898-1908. The listed take in the 10 years of record within this interval ranged from 931,000 pounds in 1903 to 3,848,000 pounds in 1906 and averaged 1,931,000 pounds. The true catch may, of course, have been higher. The Michigan statistics for 1911-1925 are so obviously incomplete in many years as to warrant little comment. Figures for 1918, 1919, and 1925 prove that production did exceed 1 million pounds in some years.

If the assumption that the "bluefins" recorded by Wisconsin for Lake Michigan (except Green Bay) were chubs is correct, that state had a brisk chub fishery in the 1890's. In 1893-1896 the take ranged from 1,476,000 pounds in 1893 to 3,000,000 in 1896. Recorded production was low, however, in 1897 and 1899. (Statistics for the latter year, taken from a Federal report, are incomplete--see earlier.)

The Federal records for chub production in Wisconsin in 1903 and 1908 also were incomplete; hence we have little knowledge of the extent of the fishing activity in the first part of the present century. Production was fairly high, however, in 1909 (3,526,000 pounds) when the State resumed maintenance of records and introduced the category "chubs". (State records continued to list bluefins for Lake Michigan proper but they made up an unimportant percentage of the total for chubs.) Over the period 1909-1925 the recorded take ranged from 955,000 pounds in 1921 to 4,183,000 pounds in 1918 and averaged 2,602,000 pounds.

The Michigan-Wisconsin totals are of limited value because most of the available ones are for years in which the statistics for at least one of the states are open to strong suspicion. The highest recorded yield was 5,763,000 pounds in 1918.

Production in 1926-1953.--Beginning with 1926 when the Bureau of Fisheries introduced the category of chubs and the states had established the practice of compiling records for all chubs separately from lake herring, the chub statistics for Lake Michigan were freed from the systematic defects that had made them undependable for so many earlier years. This same year also marks the beginning of greater interest in chubs for smoking since the smoked-fish trade lost a major source of supply with the collapse of the Lake Erie cisco fishery in 1925.

The principal defect of the 1926-1953 statistics (table 2) lies in the earlier figures for Indiana. The records for that state show a small but fairly stable production in 1926-1941 that ranged from 63,000 pounds in 1941 to 352,000 pounds in 1934 and averaged 201,000 pounds for the 16 years. The sudden drop in 1942 and the lack of any reported production of chubs for Indiana since 1943 do not reflect an end of chub production by Indiana fishermen but rather came from improvement in the handling of statistics. It is questionable whether any substantial quantities of chubs ever have been caught from the shallow Indiana waters. Fishermen from that state who have wished to fish for chubs have of necessity purchased non-resident licenses from the State of Michigan (in addition to their Indiana licenses) and have carried on their operations in Michigan waters. In reporting their catches they seem regularly to have submitted identical records to the two states. Most or all of the chubs listed for Indiana, therefore, actually were caught in Michigan, and furthermore were included in the statistics for both states. The lake totals accordingly, are too high by approximately the amount of the Indiana catch[6/]. Fortunately this take at no time made up a large percentage of the Lake Michigan total (table 3). An adjustment of the statistics to compensate this error would be valid but is believed inadvisable because of their long standing in printed records.

6/ The Indiana statistics for lake trout offered a similar problem (Hile, Eschmeyer, and Lunger, 1951a).

The total production of chubs in Lake Michigan (four states combined) varied widely in 1926-1953--from 1,630,000 pounds in 1941 to 11,151,000 in 1953 (table 2, fig. 1). The catch fluctuated erratically in 1926-1932 from 3,123,000 pounds in 1932 to 5,038,000 in 1930 and averaged 4,023,000 pounds for the 7 years (table 4). The period 1933-1939 was one of consistently high yield. All catches were above 4 million pounds and in 5 of the 7 years the take exceeded 5 million pounds (peak of 6,237,000 pounds in 1934). The average for the period was 5,249,000 pounds. The next 5 years, 1940-1944, on the contrary, had consistently low yields. The catches were under 2 million pounds in 3 years (minimum of 1,630,000 pounds in 1941) and did not exceed 2,607,000 pounds (the figure for 1944). The 5-year average was 1,971,000 pounds.

The upward trend of production that started in 1942 continued without interruption through 1953. Beginning with 1949, each year set a new record high for the 1926-1953 period, and it is to be suspected that the take in most, if not all, of these years also was higher than at any time before 1926. The average catches (table 4) of 3,952,000 pounds in 1945-1948 and 9,852,000 pounds in 1949-1953 are of limited significance, since the most important feature of each period was the rapid increase.

The percentage distribution of the annual catch of chubs among the four states (table 3) followed a definite pattern. Since most of the reported Indiana production is known to have been taken in Michigan, Indiana can be assigned last place in all years despite listed percentages in 1926 and 1927 that were higher than those for Illinois. It should be remembered also that the true percentages for other states were a little higher in those years in which catches are listed for Indiana.

First place was held consistently by Wisconsin. The percentage of the chubs caught in Wisconsin ranged from 42.7 in 1948 to 72.6 in 1928 and averaged 60.4 over the 28-year period. The relative contribution of Wisconsin was decidedly greater in the first than in the second half of the period; the mean percentage was 64.5 for 1926-1939 and 56.3 for 1940-1953.

Table 2.--Production of chubs in Lake Michigan, 1926-1953

(Thousands of pounds)

Year	Michigan	Wisconsin	Illinois	Indiana	Total
1926	1,324	2,041	168	207	3,740
1927	1,382	2,974	175	234	4,765
1928	647	2,724	277	104	3,752
1929	853	3,024	303	158	4,338
1930	764	3,529	540	204	5,038
1931	435	2,356	404	211	3,405
1932	328	2,143	467	185	3,123
1933	316	2,850	640	226	4,032
1934	948	4,108	828	352	6,237
1935	1,801	3,241	520	232	5,794
1936	1,501	3,422	480	272	5,674
1937	1,050	3,668	591	270	5,579
1938	1,439	3,163	525	277	5,404
1939	972	2,375	527	151	4,025
1940	237	788	556	67	1,648
1941	309	943	314	63	1,630
1942	363	1,030	354	8	1,755
1943	389	1,272	528	24	2,214
1944	479	1,675	454	...	2,607
1945	1,143	2,406	672	...	4,221
1946	1,065	2,629	830	...	4,524
1947	1,386	2,536	1,165	...	5,087
1948	2,083	2,529	1,317	...	5,929
1949	2,411	3,711	1,299	...	7,421
1950	2,330	5,656	1,305	...	9,291
1951	2,839	6,640	822	...	10,301
1952	3,288	6,830	979	...	11,098
1953	3,546	6,417	1,188	...	11,151

Table 3.--Percentage of the total Lake Michigan catch of chubs taken in the various states, 1926-1953

Year	Michigan	Wisconsin	Illinois	Indiana
1926	35.4	54.6	4.5	5.5
1927	29.0	62.4	3.7	4.9
1928	17.2	72.6	7.4	2.8
1929	19.7	69.7	7.0	3.6
1930	15.2	70.0	10.7	4.1
1931	12.8	69.2	11.8	6.2
1932	10.5	68.6	15.0	5.9
1933	7.8	70.7	15.9	5.6
1934	15.2	65.9	13.3	5.6
1935	31.1	55.9	9.0	4.0
1936	26.4	60.3	8.5	4.8
1937	18.8	65.8	10.6	4.8
1938	26.6	58.6	9.7	5.1
1939	24.1	59.0	13.1	3.8
1940	14.4	47.8	33.7	4.1
1941	19.0	57.8	19.3	3.9
1942	20.7	58.7	20.1	0.5
1943	17.6	57.5	23.8	1.1
1944	18.4	64.2	17.4	...
1945	27.1	57.0	15.9	...
1946	23.6	58.1	18.3	...
1947	27.2	49.9	22.9	...
1948	35.1	42.7	22.2	...
1949	32.5	50.0	17.5	...
1950	25.1	60.9	14.0	...
1951	27.6	64.4	8.0	...
1952	29.6	61.6	8.8	...
1953	31.8	57.5	10.7	...
Average 1/	22.9	60.4	14.0	2.7

1/ Unweighted mean of the percentages

Table 4.-- Average annual production of chubs in Lake Michigan over certain periods and percentage distribution of the catch among the states

[Thousands of pounds]

Period of years	Michigan	Wisconsin	Illinois	Indiana	Total
1926-1932					
Production	819	2,684	333	186	4,023
Percentage	20.4	66.7	8.3	4.6	...
1933-1939					
Production	1,147	3,261	587	254	5,249
Percentage	21.9	62.1	11.2	4.8	...
1940-1944					
Production	355	1,142	441	32	1,971
Percentage	18.0	57.9	22.4	1.7	...
1945-1948					
Production	1,136	2,020	797	...	3,952
Percentage	28.7	51.1	20.2	...	...
1949-1953					
Production	2,883	5,851	1,119	...	9,852
Percentage	29.3	59.4	11.3	...	...
1926-1953					
Production	1,272	3,096	651	116	5,135
Percentage	24.8	60.3	12.7	2.2	...

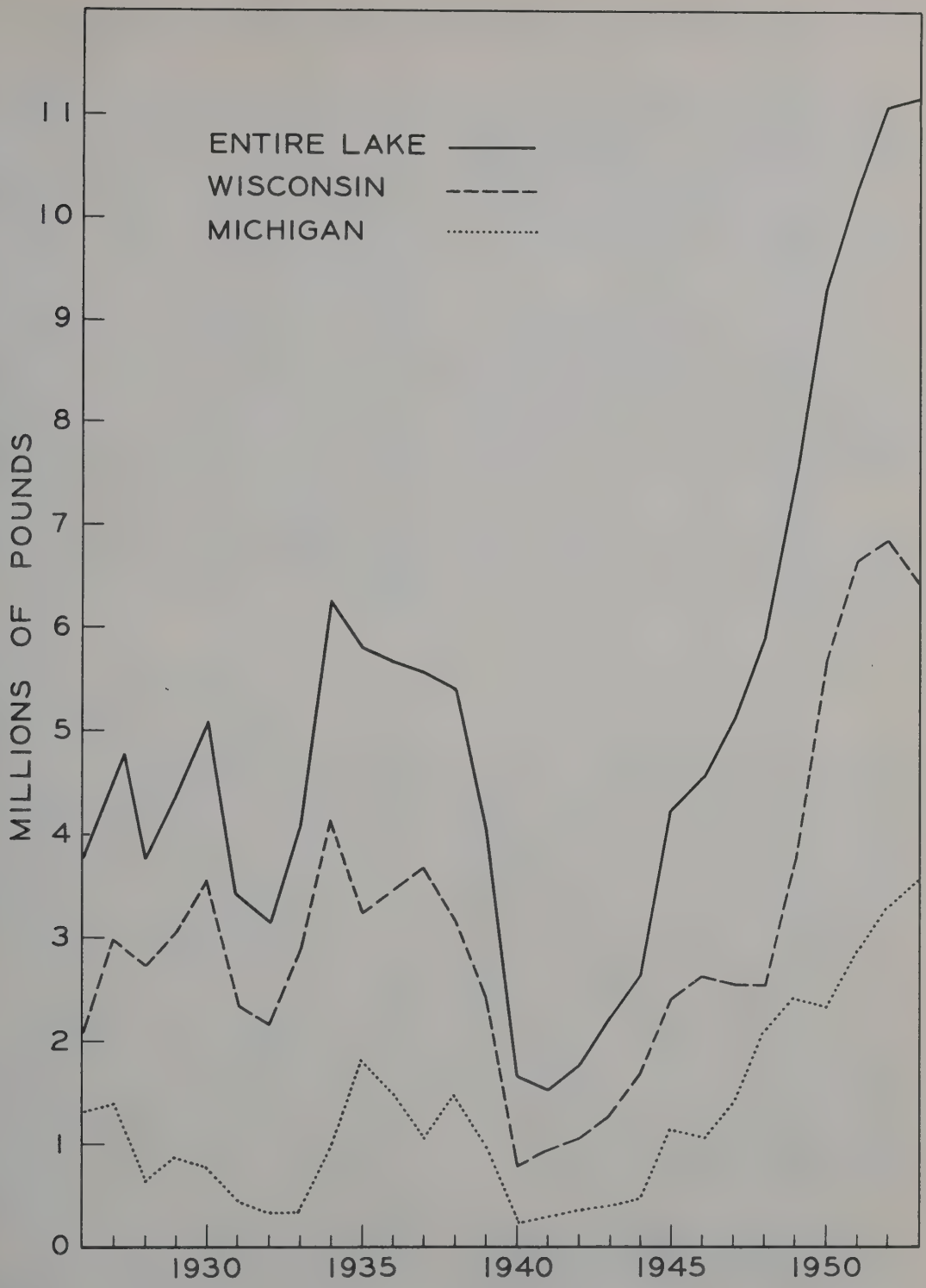

Figure 1.—Production of chubs in Lake Michigan, 1926-1953. Solid line, total production; long dashes, Wisconsin; short dashes, Michigan

Michigan held second place in Lake Michigan chub production in 23 years but yielded that position to Illinois in 1932, 1933, 1940, 1941, and 1943. The percentage for Michigan ranged from 7.8 in 1933 to 35.4 in 1926. In this state, contrary to the situation in Wisconsin, the percentages averaged lower in the earlier years (average of 20.7 for 1926-1939) than in the later years (average, 25.0).

The variation of the percentage contribution of Illinois to the Lake Michigan catch of chubs was extremely wide--from 3.7 in 1927 to 33.7 in 1940. The 28-year average was 14.0 percent. As was true in Michigan, the average percentage in Illinois was lower in 1926-1939 (10.0 percent) than in 1940-1953 (18.0 percent).

The percentage distribution of chub production as computed from average catches over various periods of years (table 4) show the same general situation as was described from means of percentages of individual years (table 3).

Production of chubs in statistical districts, 1929-1953

Because of the limited area of Lake Michigan waters within the boundaries of Illinois and Indiana, statistical districts have not been established in either state. Michigan waters, however, have been divided into 8 districts and Wisconsin waters into 6 (fig. 2). (The indicated boundary between M-2 and M-3, used for all other species does not hold for chubs; all catches of chubs west of the Beaver and Fox Islands have been assigned to M-2 in order to separate the fishery of the northern end of the open lake from that conducted between the islands and the eastern shore.) Records of annual production are on hand for Michigan districts starting with 1929. In Wisconsin, where detailed analyses are just beginning, these records are available for 1953 only. (Statistical reports submitted by Wisconsin fishermen, starting in 1936, will make possible the backward extension of detailed statistical analyses through that year.)

State of Michigan, 1929-1953.--All State of Michigan districts, except the shallow-water Green Bay district, M-1, have at times produced sizable catches of chubs (table 5, figs. 3-9). Because of its insignificant contribution, M-1 is ignored in most later discussions.

Despite some exceptions to trend and differences in the timing and extent of fluctuations, the variations in the annual catch of chubs in the several districts exhibited many similarities. In the first year of record, 1929, the take of chubs was near (M-3) or above the 1929-1943 average (these years are employed as a base, or period of reference, in treatments of State of Michigan statistics) in every district but M-6 and M-8 and the combined catch of 853,000 pounds was 9 percent above the 15-year mean of 780,000 pounds (fig. 10). A general downward trend (decreases in 5 of the 7 districts) carried the total catch to slightly below average in 1930 and a sharp drop of production occurred in 1931 (decreases in all districts but M-6 which had extremely small catches in both 1930 and 1931). The year 1931 was the first of a 3-year period of extremely low yield. Only in the relatively small district M-4 did the catch reach or exceed average, and for the combined districts the take amounted to 41 percent (1933) to 56 percent (1931) of average.

The catch of chubs rose sharply in 1934, the first in a 6-year period of generally high production. The take was well above average in all 7 districts in both 1935 and 1936, and in the remaining four years exceeded the mean in 6 districts in 1934, 5 in 1938 and 1939, and 4 in 1937. Highest levels attained were more than 3 times the 1929-1943 average in M-2 (1936) and M-5 (1935) and exceeded twice that average in all remaining districts but M-7. The high yields in M-3 in 1938, and in M-4 and M-5 in 1935 have not been equalled in subsequent years. For the combined districts the catch ranged from 121 percent of average in 1934 to 231 percent in 1935.

The sharp drop from 972,000 pounds in 1939 to 237,000 pounds (the lowest figure of modern record) in 1940 introduced a 5-year interval of below average production. The decline was general; with the exception of M-8 in 1942 and 1943 the catch was below average (usually by a wide margin) in every district in every year of the period. The total rose gradually during the 5 years from 30 percent of the 1929-1943 mean in 1940 to 61 percent in 1944.

The rise in the production of the combined districts that started in 1941 continued with

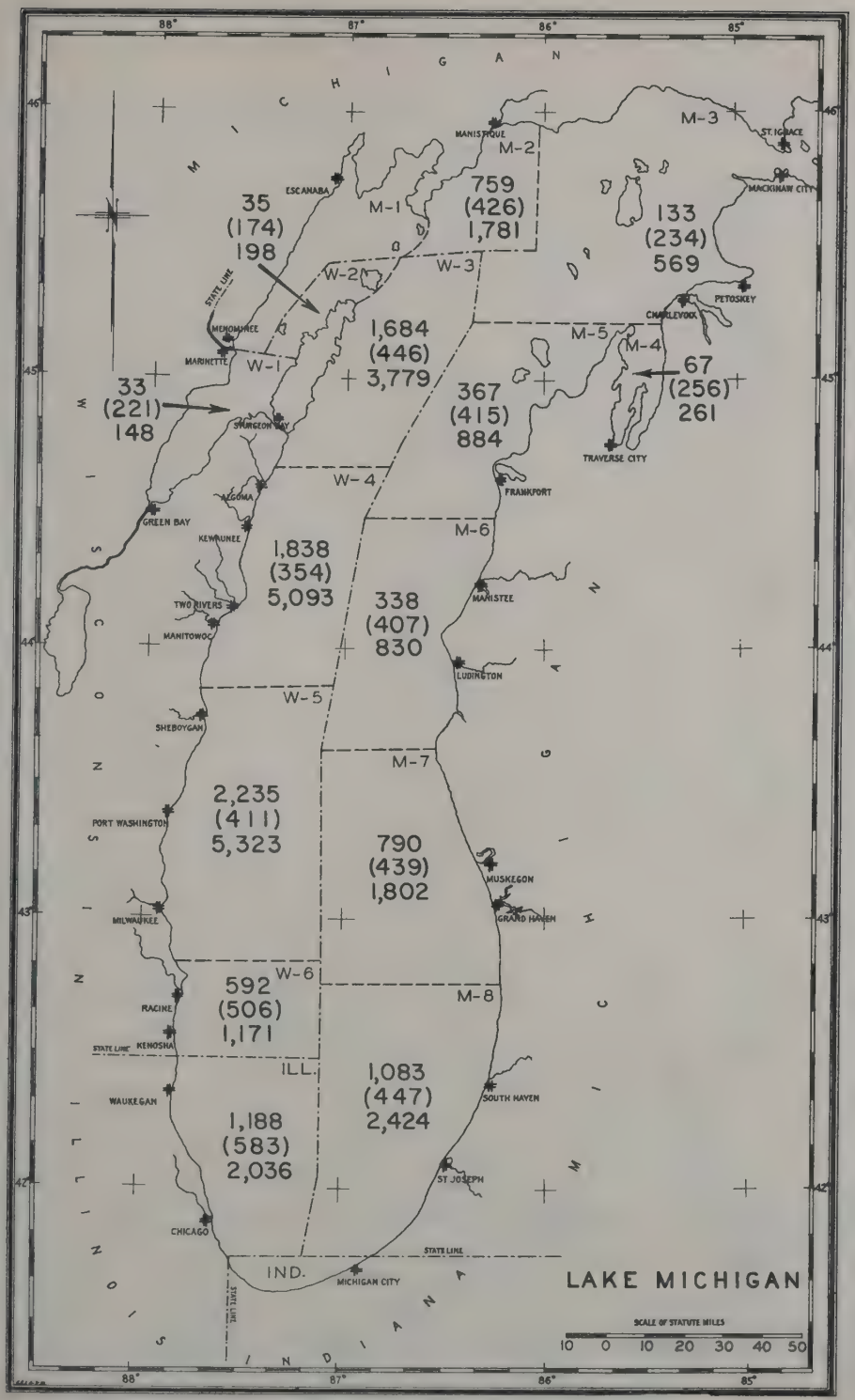

Figure 2.—Map of Lake Michigan showing boundaries of the statistical districts (Wisconsin, W-1, W-2,···; Michigan, M-1, M-2,···). The statistics shown for the districts are 1953 records of production in thousands of pounds (top), catch in pounds per unit of effort (middle—in parentheses), and number of lifts of 10,000 linear feet of chub gill nets (bottom).

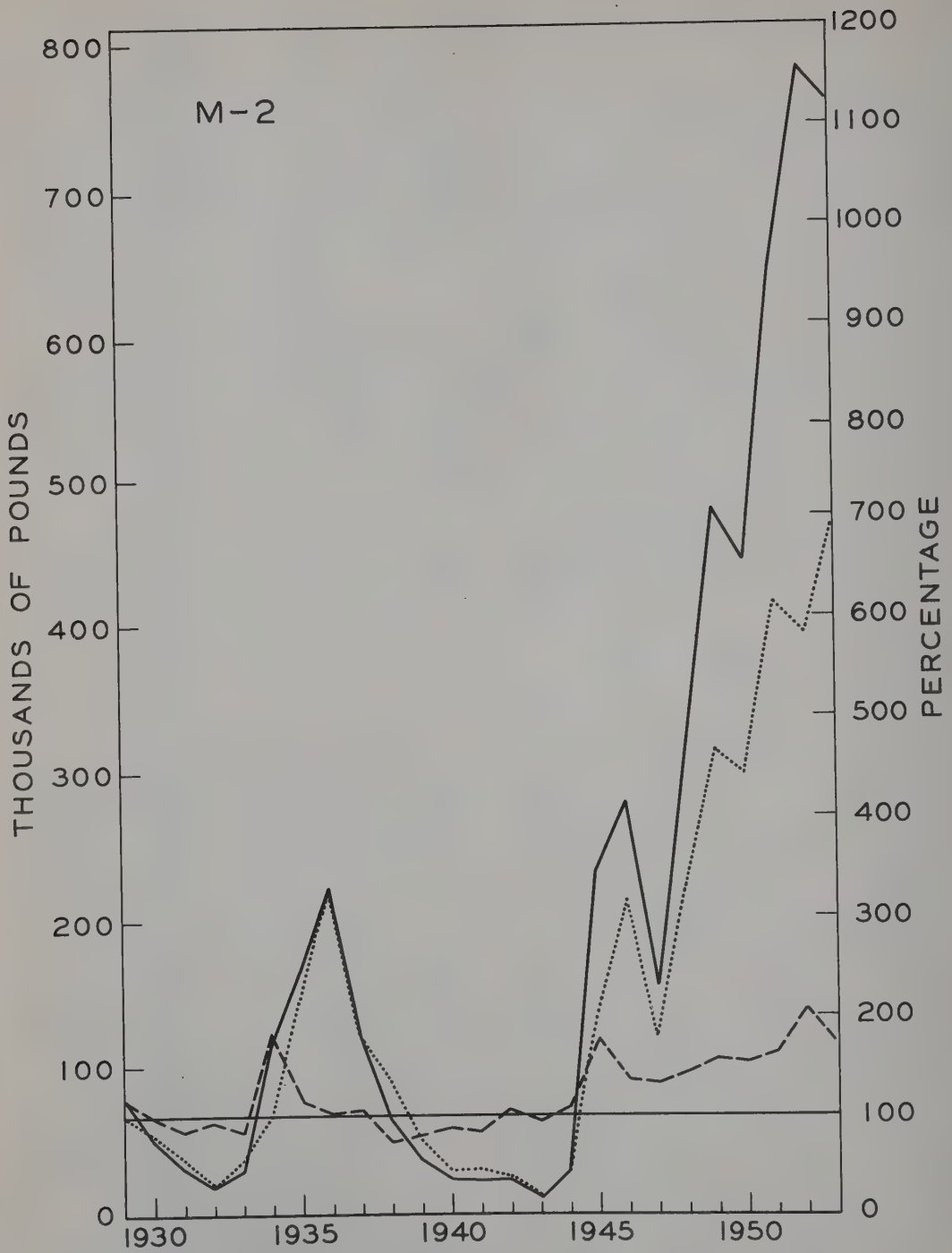

Figure 3.--Production (solid line), abundance index (long dashes), and fishing-intensity index (short dashes) for chubs in district M-2, 1929-1953. Scale at left applies only to production; scale at right is in terms of 1929-1943 mean.

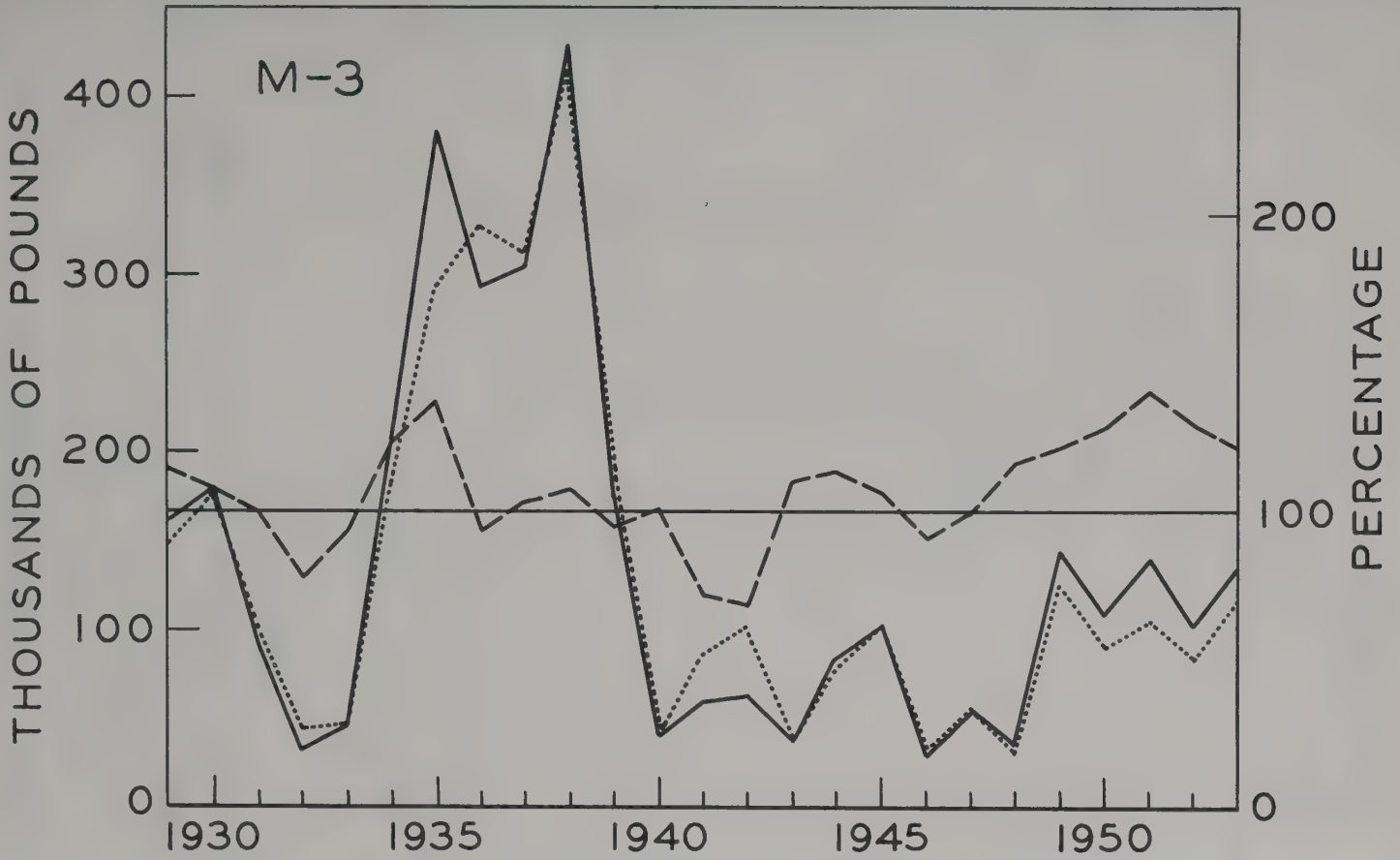

Figure 4.--Production (solid line), abundance index (long dashes), and fishing-intensity index (short dashes) for chubs in district M-3, 1929-1953. Scale at left applies only to production; scale at right is in terms of 1929-1943 mean.

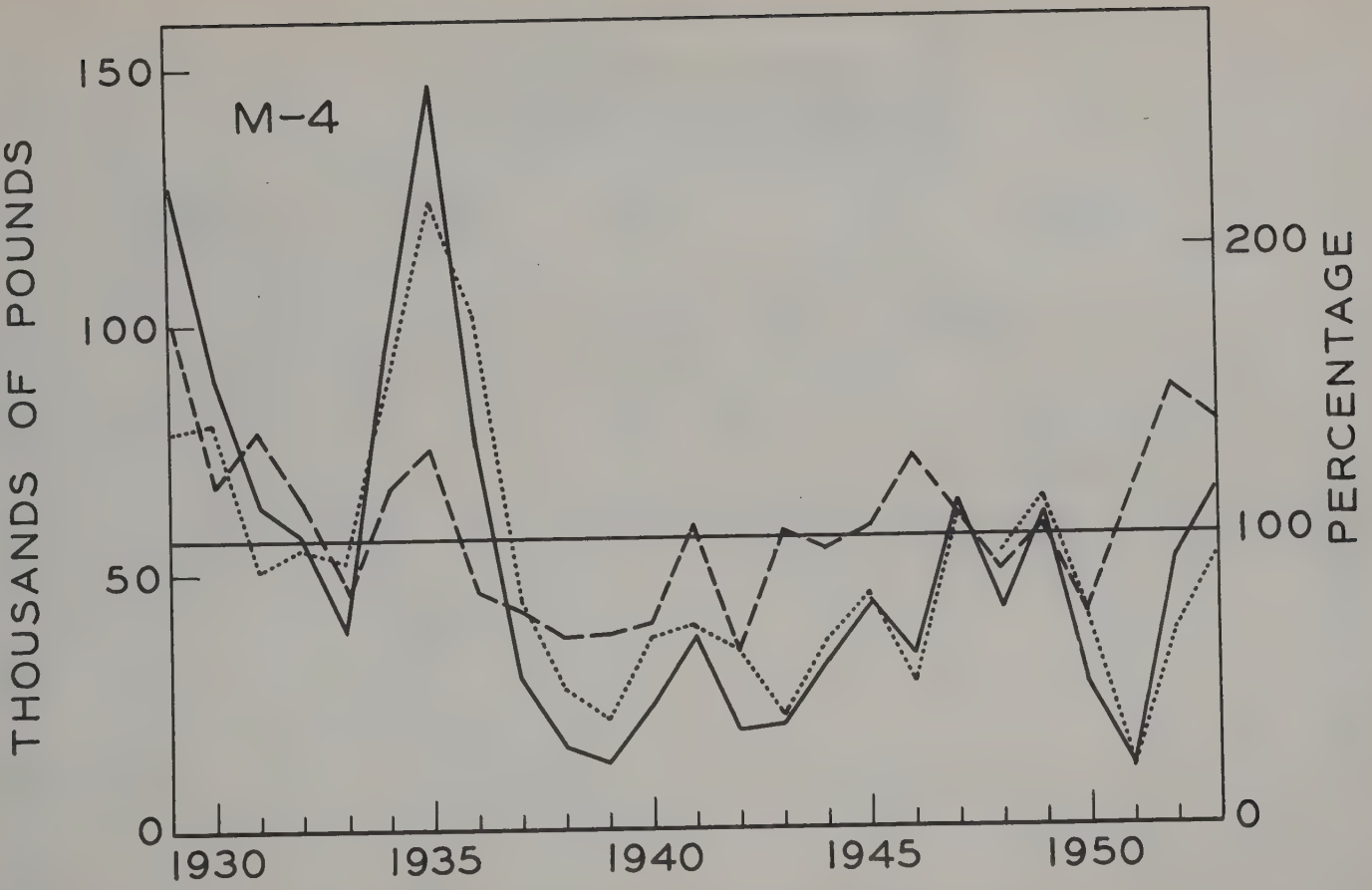

Figure 5.--Production (solid line), abundance index (long dashes), and fishing-intensity index (short dashes) for chubs in district M-4, 1929-1953. Scale at left applies only to production; scale at right is in terms of 1929-1943 mean.

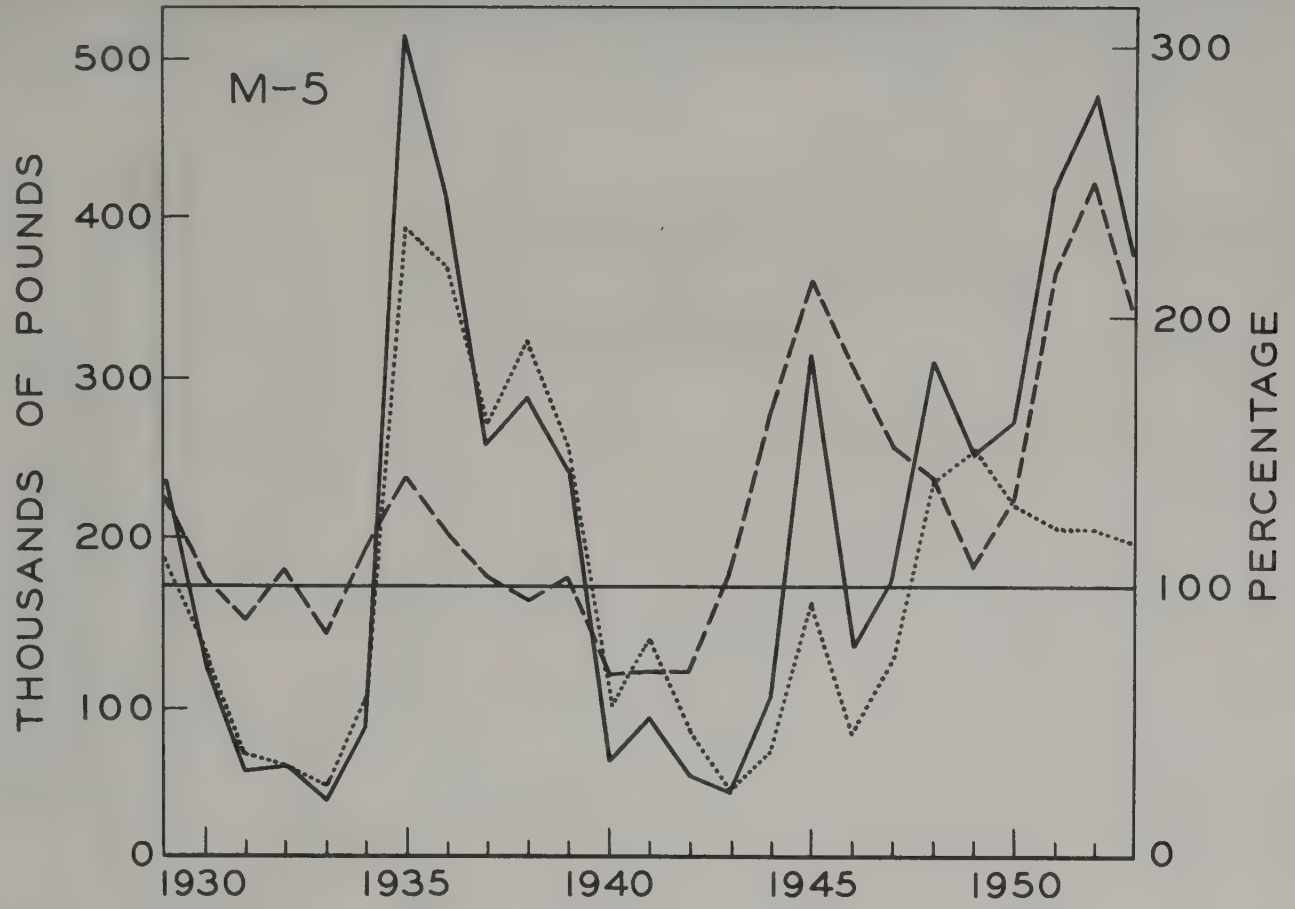

Figure 6.--Production (solid line), abundance index (long dashes), and fishing-intensity index (short dashes) for chubs in district M-5, 1929-1953. Scale at left applies only to production; scale at right is in terms of 1929-1943 mean.

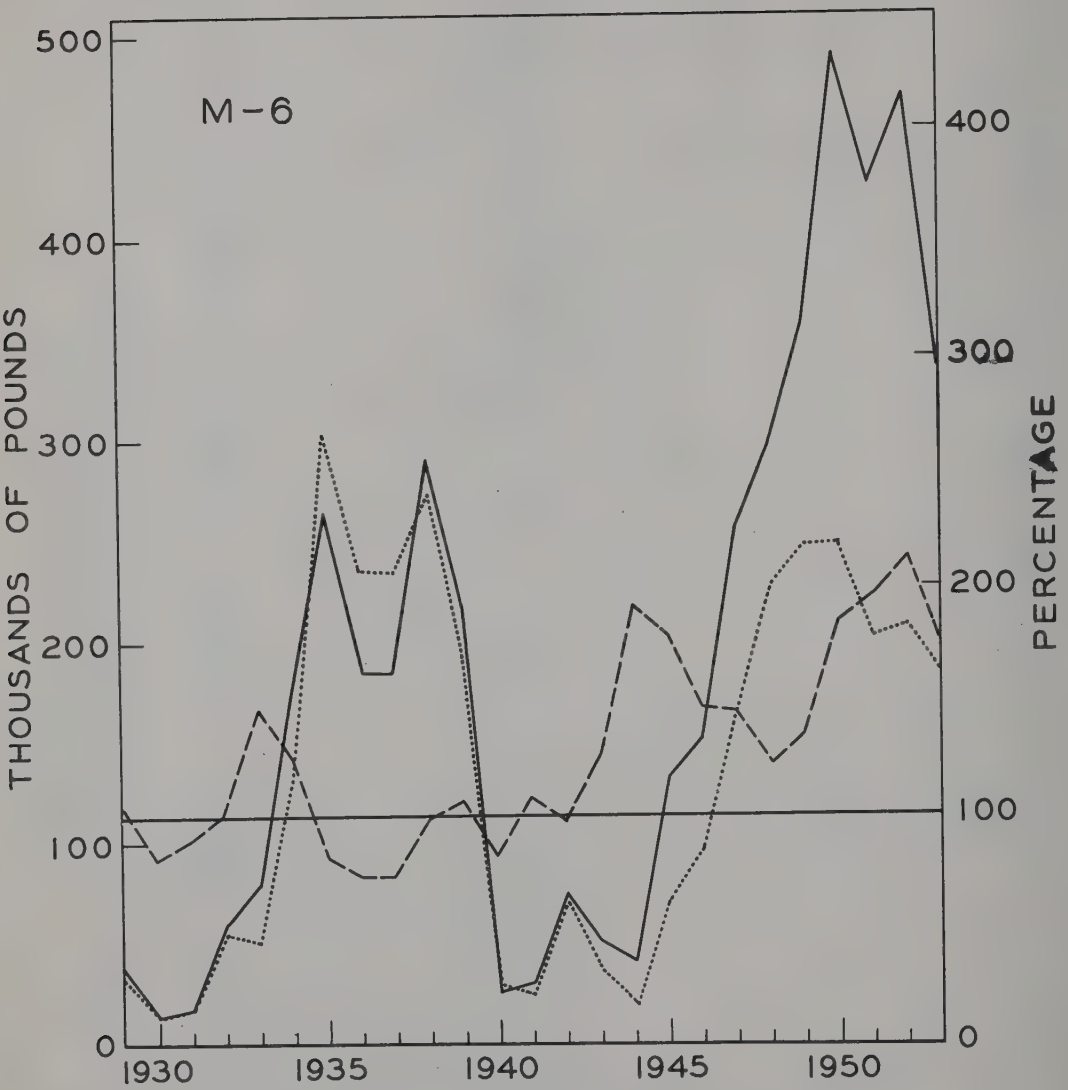

Figure 7.--Production (solid line), abundance index (long dashes), and fishing-intensity index (short dashes) for chubs in district M-6, 1929-1953. Scale at left applies only to production; scale at right is in terms of 1929-1943 mean.

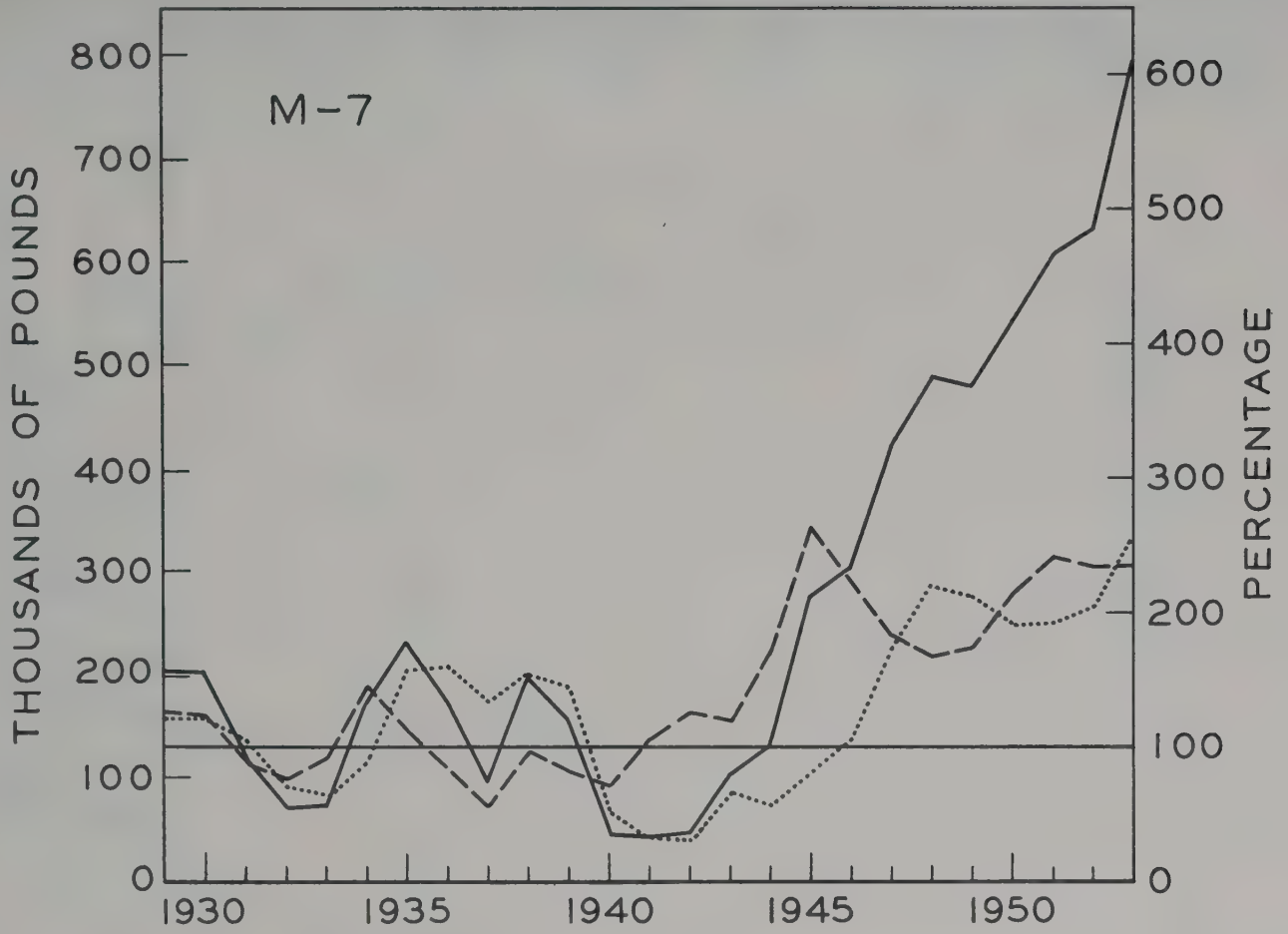

Figure 8.--Production (solid line), abundance index (long dashes), and fishing-intensity index (short dashes) for chubs in district M-7, 1929-1953. Scale at left applies only to production; scale at right is in terms of 1929-1943 mean.

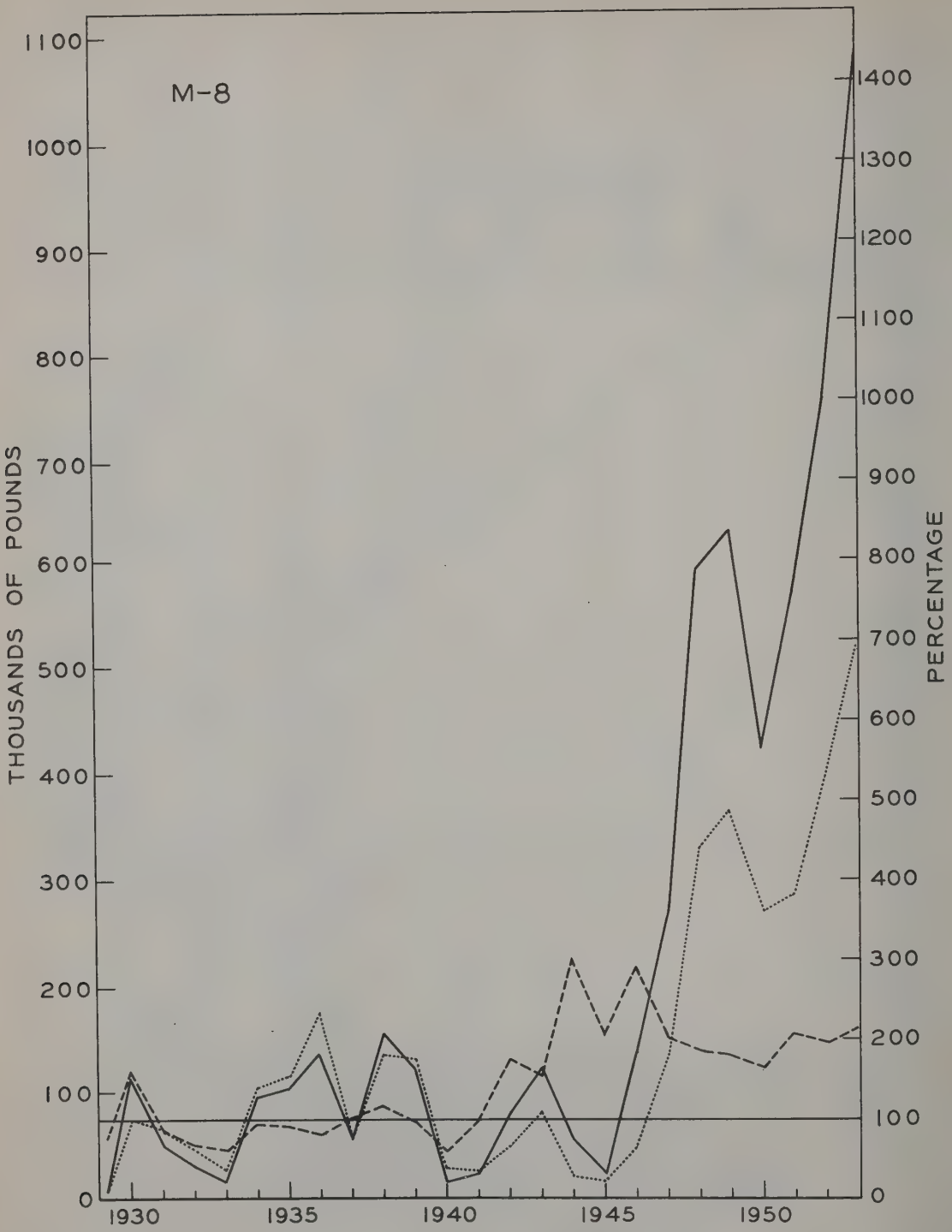

Figure 9.--Production (solid line), abundance index (long dashes), and fishing-intensity index (short dashes) for chubs in district M-8, 1929-1953. Scale at left applies only to production; scale at right is in terms of 1929-1943 mean.

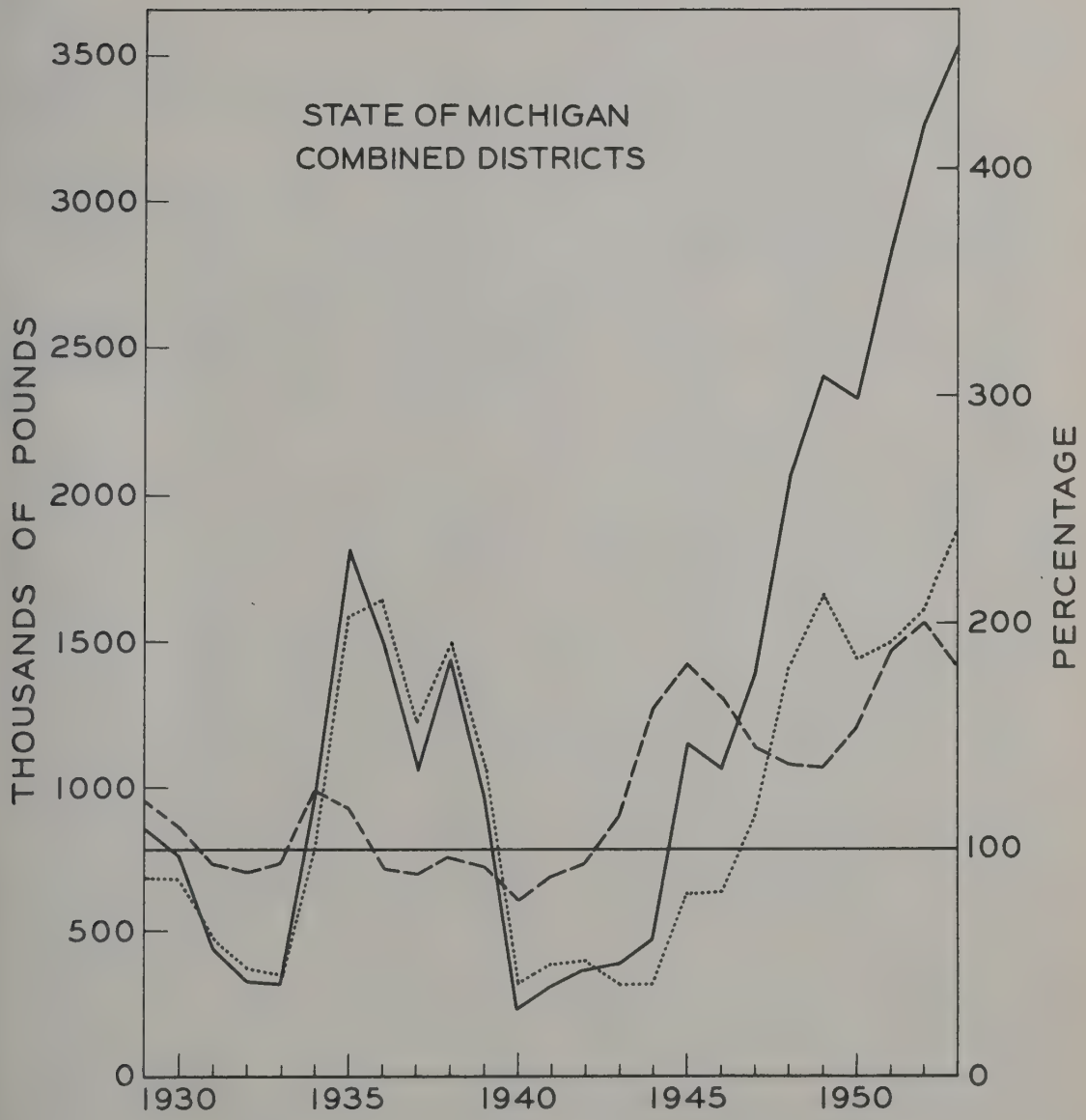

Figure 10.--Production (solid line), abundance index (long dashes), and fishing-intensity index (short dashes) for chubs in the combined districts of the State of Michigan, 1929-1953. Scale at left applies only to production; scale at right is in terms of 1929-1943 mean.

Table 5.--Production of chubs in the statistical districts of the State of Michigan waters of Lake Michigan

[Thousands of pounds]

Year	District								Total	Percentage of average for 1929-1943
	M-1	M-2	M-3	M-4	M-5	M-6	M-7	M-8		
1929	7	77	160	126	234	37	205	7	853	109
1930	2	50	177	89	119	13	201	113	764	98
1931	6	33	91	65	53	17	122	50	435	56
1932	2	19	32	57	55	60	73	31	328	42
1933	1/...	30	43	39	34	79	76	16	316	41
1934	1/...	115	212	96	83	176	171	96	948	121
1935	1/...	165	376	148	515	263	232	103	1,801	231
1936	2	219	291	76	414	187	177	135	1,501	192
1937	1/...	121	303	30	259	185	99	54	1,050	135
1938	5	64	426	17	286	289	198	155	1,439	184
1939	4	38	174	13	244	219	157	124	972	124
1940	1	24	39	24	59	25	47	16	237	30
1941	8	24	58	38	86	29	44	23	309	40
1942	5	25	64	20	51	74	47	78	363	47
1943	2	11	38	20	40	51	106	122	389	50
Average, 1929-1943	3	68	166	57	169	114	130	75	780	100
Percentage	0.4	8.7	21.2	7.3	21.6	14.5	16.7	9.6	...	...
1944	2	30	82	32	102	41	128	60	479	61
1945	10	233	102	44	314	133	276	31	1,143	146
1946	1/...	279	29	34	132	152	303	136	1,065	136
1947	1/...	155	51	64	172	256	424	264	1,386	178
1948	7	308	33	43	310	297	489	597	2,083	267
1949	3	478	142	62	253	357	479	637	2,411	309
1950	22	444	108	27	272	490	543	424	2,330	299
1951	11	649	137	11	418	426	609	576	2,839	364
1952	16	783	102	52	477	470	633	755	3,288	421
1953	9	759	133	67	367	338	790	1,083	3,546	454
Average, 1944-1953	8	412	92	44	282	296	467	456	2,057	264
Percentage	0.4	20.0	4.5	2.1	13.7	14.4	22.7	22.2	...	...

1/ Less than 500 pounds

only two minor irregularities (1946 and 1950) to a maximum of 3,546,000 pounds (454 percent of the 1929-1943 mean) in 1953. The trend during the 1941-1953 interval was irregularly upward in all 7 chub-producing districts, but in M-3 it was too weak to carry the take to the 15-year base level and in M-4 the catch exceeded the 1929-1943 average only 3 times (1947, 1949, and 1953). The increase in the catch was large in M-5 but the highest take (in 1952) of recent years was still below the 1935 figure. New production records were set in the remaining 4 districts. Highest levels were reached in M-8 where the 1953 catch of 1,083,000 pounds was 14-1/2 times the 15-year mean and in M-2 where the 1952 take was 11-1/2 times the 1929-1943 figure. Maxima attained in the remaining 2 districts were 790,000 pounds (608 percent of average) in M-7 in 1953 and 490,000 pounds (430 percent of average in M-6 in 1950.

Differences among the districts as to the extent of recent increases in chub production--especially the high levels reached in M-2 and M-8 and the failure of production in M-3 even to attain the base-period mean--led to considerable changes from 1929-1943 to 1944-1953 in the percentage distribution of the catch (table 6). Greatest improvement of relative importance occurred in M-8 which moved from fifth to second position and had a percentage in 1944-1953 that was 2.31 times that of 1929-1943. Improvement was nearly the same in M-2 which advanced from sixth to third and had a ratio of 2.30 for the two percentages. M-7 changed from third to first position but the percentage for 1944-1953 was only 1.36 times that for 1929-1943. M-6 and M-4 held fourth and seventh rank, respectively, in both periods. The percentage contribution of M-6 changed little (ratio of 0.99) but that of M-4 declined severely (ratio of 0.29). Major loss of relative importance in chub production took place in M-3 which dropped from second to sixth position and had a 1944-1953 percentage only 0.21 of that of 1929-1943. M-5 also suffered a large drop in rank (from 1 to 5) but experienced a relatively modest decline in percentage (ratio, 0.63).

7/ Even this small catch included relatively few bona fide chubs; a large proportion was made up of fat lake herring.

State of Wisconsin, 1953.--Records of the 1953 production of chubs in Wisconsin districts (fig. 2 and table 7--statistics on fishing effort and catch per unit of effort are discussed in later sections) show that here as in Michigan almost the entire take comes from Lake Michigan proper. The two Green Bay districts (W-1 and W-2) accounted for little more than 1 percent of the total catch.[7/] Among the remaining districts the catches fell in the order, W-5, W-4, W-3, and W-6 (last district of limited area). If allowance is made for the small size of W-6, it may be stated that Wisconsin districts were far more productive than the adjacent Michigan waters.

Abundance of chubs in Lake Michigan, 1929-1953

Attempts to trace fluctuations in the abundance of chubs from records of the catch-per-unit-effort of the small-mesh gill nets, which take the great bulk of the production, are handicapped by changes in laws on the construction (especially mesh size) of the nets, variation in the enforcement of those laws, and changes in the type of twine from which the nets are made. The laws relating to chub nets are, of course, a matter of readily accessible record. In Michigan, the state for which we have the most extensive statistics on catch per unit effort (1929-1953), the minimum legal mesh size for chub gill nets was 2-3/4 inches, stretched measure[8/] (actually the legal mesh size was 2-3/4 to 2-7/8 inches, but only the minimum need be considered here). In 1933 the mesh size for chub gill nets was reduced to 2-5/8 inches, stretched measure, and in 1939 the legal

8/A stiff steel rule with a notch in the side at a distance from the end corresponding to the minimum legal mesh size was used for gaging the nets. The end of the rule was placed in the mesh; if the mesh could then be fitted into the notch without breaking the twine or slipping the knot, that mesh was legal. (State laws include stipulations on the location of meshes to be gaged and on the number that must be measured to determine the legal status of a net.) Flexible twine can be stretched so much with this method of measurement that the mesh sizes of gill nets as actually fished are far below the stipulated legal minimum.

Table 6.--Comparison of the relative importance of State of Michigan districts in the contribution to total production of chubs in 1929-1943 and 1944-1953

District	1929-1943		1944-1953		Ratio of percentages	Change of rank
	Percentages of total catch	Rank	Percentages of total catch	Rank		
M-5	21.6	1	13.7	5	0.63	-4
M-3	21.2	2	4.5	6	0.21	-4
M-7	16.7	3	22.7	1	1.36	2
M-6	14.5	4	14.4	4	0.99	0
M-8	9.6	5	22.2	2	2.31	3
M-2	8.7	6	20.0	3	2.30	3
M-4	7.3	7	2.1	7	0.29	0

Table 7.--Production of chubs (all gears), fishing effort with 2 1/2-inch-mesh gill nets (units of 10,000 linear feet in which chubs were taken) and catch per unit of effort in the statistical districts of the State of Wisconsin waters of Lake Michigan, 1953

District	Production		Fishing effort	Catch per unit effort (pounds)
	Thousands of pounds	Percentage of total		
W-1	33	0.5	148	221
W-2	35	0.5	198	174
W-3	1,684	26.3	3,779	446
W-4	1,838	28.7	5,093	354
W-5	2,235	34.8	5,323	411
W-6	592	9.2	1,171	506
Total	6,417	...	15,712	...

mesh was changed to 2-1/2 inches, flexible-rule measure.9/ This last change had little actual effect on the legal mesh size since a 2-1/2 inch mesh, flexible-rule measure, is roughly equivalent to 2-5/8 inch mesh, stretched measure. The 2-1/2 inch mesh continued to be the legal minimum in Michigan through 1953.

In Illinois, where records of catch-per-unit-effort start with 1950, the minimum legal mesh size for chubs was 2-3/8 inches, flexible rule, in 1950 through June 30, 1951; after June 30, 1951, it was 2-1/4 inches. The minimum mesh size in Wisconsin was 2-1/2 inches, flexible rule, in 1953, the one year for which we have these records. There are no records of catch-per-unit-effort for Indiana.

The extent of variability in the enforcement of the law and the effects of lax enforcement on records of catch-per-unit-effort are difficult to determine. It is well known that over extended periods little enforcement was attempted. Concerning this matter Van Oosten has written as follows: 10/

"As a matter of fact, for many years none of the four states fronting Lake Michigan enforced its law on the mesh of chub nets. Because of this lack of enforcement the mesh in actual use became smaller and smaller until many nets had meshes as small as 2-1/4 and 2-1/8 inches, stretched measure. Michigan fishermen, however, seldom if ever employed meshes smaller than 2-1/2 inches. It is safe to say that for many years not a legal mesh net was actually employed for chubs in the Lake Michigan waters of Wisconsin, Illinois and Indiana."

Dr. Van Oosten also has advised us personally that in the early 1930's Michigan officials were deliberately lenient in the enforcement of the chub-net law pending issuance of recommendations on mesh size resulting from the experimental fishing of the Fulmar. (Actually, the recommendation of 2-3/4 inch mesh was ignored by all four states.) It seems possible, therefore, that the change of minimum mesh size from 2-3/4 to 2-5/8 inches in 1933 had little effect on the gear fished by State of Michigan fishermen; it may only have made legal the equipment long in use. Since enforcement of the mesh law in Michigan has been reasonably efficient the last 20 years or longer and since the shift in 1939 from 2-5/8 inch mesh, stretched measure, to 2-1/2 inch mesh, flexible rule, entailed little real change, it appears that the effects of changes in the law on records of catch-per-unit-effort were smaller than might be suspected--indeed, may have been of limited consequence.

There is reason to believe that in 1953 most nets fished in Wisconsin had legal-sized meshes. We do not know of changes in enforcement policies in Illinois in 1950-1953.

Two changes in the twine in chub gill nets have biased our records of catch-per-unit of effort. First was the substitution of "Sea Island" cotton, a highly flexible twine, for the traditional linen webbing. According to Van Oosten (see footnote 10) this changeover started in Wisconsin in 1929. These "rubber nets" had two significant characteristics: first, they were good fish-catchers and second, the extreme flexibility of the twine made laws on minimum mesh size largely ineffective under the stretched-measure system of gaging. (This second "advantage" was much reduced by the introduction of the flexible rule.) Once the cotton nets were introduced their use spread rapidly and soon became general throughout the lake.

9/ A thin steel rule of a length equal to the minimum mesh size is bent slightly, inserted in the mesh, and released; if it straightens within 2 seconds without slipping the knot or breaking the twine, the mesh is legal. Inasmuch as the rules are so constructed that they exert pressure of approximately 1 pound when bent so that the center is deflected 1/10 of the length, this method of gaging is objective and influenced only moderately by the flexibility of the twine.

10/ "Brief resumè of the history of the changes in the size of mesh employed in chub nets in Lake Michigan, particularly in Wisconsin waters," by John Van Oosten; this memorandum was prepared in 1941 and was mimeographed by the Wisconsin Conservation Department in 1947.

The second major change in chub gill nets was the conversion to nylon twine. According to the best records we can obtain, the first nylon nets were fished in Lake Michigan (Wisconsin and Indiana) in 1946. Some fishing was being done with them from a majority of ports in all areas of the lake by 1948 and 1949, and the changeover was complete or nearly so in most ports by 1952 or 1953. Despite its current general use nylon twine has met resistance. Some fishermen reverted to cotton after trying nylon. At one port 50 percent of the chub nets lifted were still cotton as recently as 1954.

It is impossible to offer a definite estimate of the relative efficiencies of nylon and cotton chub nets. The opinions of fishermen vary widely but a "median" estimate probably would place the nylon nets as between 2 and 3 times as efficient as cotton. The actual ratio doubtless depends on such factors as size and flexibility of thread, method of hanging, and kinds of fish on the grounds. A major disadvantage of nylon nets is their embarrassing capacity for taking "trash"--bloaters and small chubs of other species. The early difficulties with trash fish were eased somewhat by hanging the nets more open than the one-half basis 11/ that was usual with cotton and linen twine. Benefits from this change in method of hanging seem to be lessened, however, by an increasingly higher percentage of small chubs, especially bloaters, on the grounds.

In the study of fluctuations in "abundance" it is important not only to keep in mind the sources of bias just outlined but also to remember that the records of catch and the indices of availability computed from them are based on a group of species of changing composition.

State of Michigan, 1929-1953.--The indices of abundance (availability) in Michigan districts (table 8) were computed from records of the annual average catch per lift of small-mesh gill nets that took chubs (table 9; the original file records carried one additional significant figure). The fluctuations of abundance are shown graphically in figures 3-9.

11/ A net being "on the half" has 2 feet of netting, flat mesh, on 1 foot of maitre.

Fishing success varied widely in individual districts of State of Michigan waters in the 25 years, 1929-1953. The highest abundance index for chubs in individual districts ranged from 2.1 (M-3) to 5.2 (M-8) times the lowest (table 10). For the combined districts the highest abundance (200 in 1952) was 2.6 times the lowest (78 in 1940). Minimum availability occurred in all districts within the period 1936-1942. Maximum abundance was reached in 1929 in M-4 but in the other districts it occurred in 1944, 1945, 1951, or 1952. The indices of 264 in M-7 in 1945 and 299 in M-8 in 1944--highest values in any district--are especially significant because these peaks were attained without the use of nylon nets. Nylon of course did not contribute to the M-4 maximum (1929) but this twine unquestionably was important in the remaining districts in which the best fishing occurred in 1951 or 1952. The lowest as well as the highest abundance indices were in M-7 (56 in 1937) and M-8 (57 in 1940).

For comparisons between districts of the fluctuations in the abundance index it is believed desirable to divide the 25 years into the sub-periods 1929-1943 and 1944-1953. The generally high level of yield per unit effort in 1944-1953 does not reflect the type of "natural fluctuation" in abundance in which we are primarily interested. The statistics for the later years, beginning in some districts as early as 1946, were affected by the gradual introduction and (in most areas) ultimate dominance of the relatively efficient nylon twine. Nylon nets had no effect on the statistics of the earlier years of the 10-year period, but the declining abundance of lake trout probably did since chubs are the principal food of the trout (Van Oosten and Deason, 1938). Even though the bloater, of limited value commercially, benefited most from the disappearance of lake trout, the abundance of other species also probably was affected. The data given by Hile, Eschmeyer, and Lunger (1951a) indicate that the decline in the abundance of lake trout that led to the collapse of the trout fishery was under way in M-2, M-3, and M-4 before the middle 1940's. The abundance of lake trout did not once equal the 1929-1943 average in M-2 after 1941, in M-3 after 1943, or in M-4 after 1944. The first in the series of record-low levels of availability of

Table 8.--Abundance of chubs in the statistical districts of the State of Michigan waters of Lake Michigan and for the districts combined

[Expressed as percentages of the 1929-1943 average]

Year	District							Average[1/]
	M-2	M-3	M-4	M-5	M-6	M-7	M-8	
1929	116	114	174	135	105	126	80	121
1930	98	107	120	103	81	124	159	110
1931	86	99	138	88	90	89	79	94
1932	93	78	114	106	101	77	68	90
1933	82	94	81	83	147	91	60	94
1934	180	124	118	114	125	146	94	127
1935	116	136	131	140	82	111	91	118
1936	102	94	82	120	74	84	79	93
1937	106	103	72	103	74	56	99	89
1938	73	107	66	95	99	97	114	96
1939	79	95	67	102	106	81	96	93
1940	88	100	71	68	83	71	57	78
1941	82	72	104	69	108	104	97	88
1942	104	67	61	69	98	124	172	94
1943	95	110	101	105	127	119	155	115
1944	108	114	96	166	192	171	299	162
1945	176	106	104	214	179	264	205	182
1946	136	96	128	182	148	222	290	168
1947	131	99	111	152	145	183	201	145
1948	142	116	87	140	123	168	186	138
1949	157	121	105	107	135	172	180	136
1950	154	128	74	133	185	216	162	154
1951	162	140	114	217	196	240	208	188
1952	206	130	151	250	212	234	197	200
1953	169	122	139	201	174	235	214	180

1/ In computation of the average the abundance index for each district was weighted by its percentage contribution to the total catch for all districts in 1929-1943

Table 9.--Catch (pounds) of chubs per lift of 10,000 linear feet of small-mesh gill nets in the statistical districts M-2 to M-8 of State of Michigan waters of Lake Michigan, 1929-1953

[Mesh sizes 2 1/2 to 2 7/8 inches, extension measure]

Year	District						
	M-2	M-3	M-4	M-5	M-6	M-7	M-8
1929	294	219	319	279	247	237	168
1930	248	204	222	212	191	233	332
1931	218	189	253	182	209	167	164
1932	236	149	212	217	235	145	140
1933	207	182	149	171	344	168	125
1934	454	239	217	235	293	272	196
1935	291	260	239	290	192	207	190
1936	258	181	150	249	173	156	166
1937	268	198	132	213	173	104	206
1938	184	204	122	197	233	181	238
1939	200	182	124	210	248	150	200
1940	221	191	131	141	195	131	118
1941	208	139	191	142	253	192	202
1942	263	129	112	142	231	232	359
1943	241	210	184	216	297	222	323
Average	253	192	184	206	234	186	208
1944	273	218	177	341	450	318	624
1945	445	204	192	442	418	494	427
1946	342	183	236	375	347	415	605
1947	331	190	205	313	340	341	419
1948	358	221	161	289	287	314	388
1949	396	233	193	220	316	321	374
1950	389	245	136	274	433	404	337
1951	409	269	210	447	459	448	434
1952	519	248	279	516	496	438	410
1953	426	234	256	415	407	439	447

Table 10.--Value and year of lowest and highest abundance indices for chubs in the State of Michigan waters of Lake Michigan, 1929-1953, and ratios of the extreme indices

District	Minimum abundance		Maximum abundance		Ratio of indices
	Index	Year	Index	Year	
M-2	73	1938	206	1952	2.8
M-3	67	1942	140	1951	2.1
M-4	61	1942	174	1929	2.9
M-5	68	1940	250	1952	3.7
M-6	74	1936	212	1952	2.9
M-7	56	1937	264	1945	4.7
M-8	57	1940	299	1944	5.2
Average	78	1940	200	1952	2.6

Table 11.--Correlation ($\bar{r}$) between fluctuations in abundance of chubs in the statistical districts of the State of Michigan waters of Lake Michigan, 1929-1943

[Absolute values of $\bar{r}$ corresponding to 1-, 5-, and 10-percent levels of probability are 0.641, 0.514, and 0.441]

District	District						
	M-2	M-3	M-4	M-5	M-6	M-7	M-8
M-2	...	0.487	0.368	0.461	0.097	0.581	0.033
M-3	0.487	...	0.431	0.706	-0.047	0.302	-0.095
M-4	0.368	0.431	...	0.568	0.030	0.460	-0.169
M-5	0.461	0.706	0.568	...	-0.155	0.246	-0.110
M-6	0.097	-0.047	0.030	-0.155	...	0.377	-0.032
M-7	0.581	0.302	0.460	0.246	0.377	...	0.508
M-8	0.033	-0.095	-0.169	-0.110	-0.032	0.508	...

lake trout were established in M-2 in 1944, in M-3 in 1945, and in M-4 in 1946. The decline of the lake trout took place later in the more southerly districts. Years of above-average abundance occurred in M-5 and M-6 as recently as 1945 and in M-7 and M-8 as late as 1947. The decline of lake trout first carried the stock to new record lows as follows: M-5, 1948; M-6, 1947; M-7 and M-8, 1949. The combined effects of the introduction of nylon netting and reduced predation by lake trout created a trend toward higher catches per unit effort that makes undesirable the inclusion of the more recent years in the study of correlations of fluctuations of availability in the several districts.

Conditions were more stable over the 15-year base period, 1929-1943. To be sure, the abundance of the predatory lake trout varied but the changes were not extreme (Hile, Eschmeyer, and Lunger, 1951a). Furthermore, changes were made in fishing laws and in the kind of twine in the nets, but the shift from linen to cotton did not bring increase of efficiency comparable to that which resulted from the introduction of nylon and, as was explained in the introduction to this section, the changes of regulations may have had no major effect on fishing success. Even though limitations of the data must be recognized the abundance indices of 1929-1943 offer our best materials for inquiry into the extent of correlations between fluctuations in the abundance of chubs in different districts.

The correlation coefficients (table 11) give some evidence of similarities between districts but do not indicate lake-wide correlation. Closest similarities were among the 4 northernmost districts, M-2 through M-5. All 6 coefficients were positive; 1 was significant at the 1-percent level (M-3, M-5), 1 at the 5-percent level (M-4, M-5), and 2 at the 10-percent level (M-2, M-3; M-2, M-5). Only the correlations of M-4 with M-2 and M-3 fell short of the 10-percent probability. Farther south, the fluctuations in abundance of chubs in M-6 gave no evidence of correlation with those in any other district. Fluctuations in M-7 were correlated significantly with those in M-2($p < 0.05$) and the correlation of M-7 with M-8 fell just short of the 5-percent level. Aside from this correlation with M-7, the fluctuation in M-8 appeared not to be correlated with those in other areas.

Discussion of the possible significance of the correlations that were found between fluctuations of chubs in different districts would be little to the point, since there is no means of judging the extent to which they were influenced by changes in the law and in the kind of twine fished and since the fluctuations involved a group of species.

Correlations were calculated also between the 1929-1943 abundance of chubs of commercial size and of the predatory lake trout and the related whitefish and lake herring (table 12). Although the predation of lake trout on chubs bore heaviest on small fish, it was not necessarily limited entirely to them. One might anticipate a possible negative correlation between the abundance of the two. The data do not, however, meet this expectation for only 3 of the 7 coefficients were negative and these had small values. The 2 largest values were both positive; that for M-6 was significant at the 10-percent level and the one for M-8 at the 1-percent level. Apparently the fluctuations in the abundance of lake trout in 1929-1943 were not great enough to exert a detectable effect on the abundance of commercially valuable chubs 12/. Some evidence exists for correlation between fluctuations in the abundance of chubs and whitefish. Six of the 7 coefficients were positive, 1 was significant at the 1-percent level (M-4), and 1 was near the 1-percent value (M-7). The only indication of correlation between the abundance of chubs and lake herring occurred in M-8 where the coefficient was significant at the 5-percent level (the fluctuations of lake herring were for districts M-6, M-7, and M-8 combined--see footnote to table 12).

12/ Further evidence that both lake trout and commercially exploitable chubs can be plentiful at the same time comes from data for M-8 in 1944 and 1945. In those years the abundance indices for lake trout were 174 and 166, respectively, and those for chubs were 299 and 205.

Table 12.--Correlation (r) between 1929-1943 fluctuations in abundance of chubs and of three other species in the statistical districts of State of Michigan waters of Lake Michigar

[Absolute values of r corresponding to 1-, 5-, and 10-percent levels of probability are 0.641, 0.514, and 0.441]

District	Lake trout	Whitefish	Lake herring 1/
M-2	0.126	-0.086	...
M-3	-0.171	0.131	...
M-4	-0.002	0.642	-0.192
M-5	-0.273	0.274	...
M-6	0.449	0.315	-0.091
M-7	0.109	0.626	-0.043
M-8	0.648	0.266	0.518

1/ Estimates of fluctuations in abundance of lake herring in M-6, M-7, and M-8 were based on the pooled data for the three districts. The one set of abundance indices obtained was correlated separately with the chub indices for each of the three districts.

The abundance indices for the combined districts (right-hand column of table 8; fig. 10) which measure the general level of fishing success give some indication of cyclic fluctuations. The index stood at 121 in 1929, dropped to 90 in 1932, increased to 127 in 1934, declined (with one exception to trend) to the 25-year minimum of 78 in 1940, rose to 182 in 1945, fell away to 136 in 1949, increased to the 25-year peak of 200 in 1952, and was 180 in 1953. The general trend of availability has been upward since 1940. Because of disturbing factors discussed earlier in the section the significance of these fluctuations is to a degree questionable. The common use of nylon twine doubtless contributed strongly to the high values of the index in the last 4 or 5 years of the period.

States of Illinois, 1950-1953, and Wisconsin, 1953.--Since records of catch-per-unit-effort are available for Wisconsin in only 1 year (table 7) and for Illinois in only 4 (table 13), indices of abundance have not been calculated for either state. The actual poundages per lift of 10,000 linear feet of chub gill nets, however, permit comparisons of the quality of fishing in various statistical districts. To facilitate these comparisons for 1953 these poundages are recorded in figure 2.

The 1953 catch per lift of "chubs" (see footnote 7) was low in both of the Wisconsin districts of Green Bay, W-1 and W-2 (table 7). Catches in the open lake, W-3 through W-6, were larger than in Green Bay and in general similar to those of contiguous waters of Michigan (an exception need not be made for M-3, since, as was explained earlier, the chub fishing in the western part of that district was assigned to M-2). Principal contrasts are provided by W-4 in which the catch of 354 pounds per lift was lower than in M-5 (415 pounds) and M-6 (407 pounds) and by W-6 where the take of 506 pounds exceeded the figures of 439 in M-7 and 447 in M-8.

The catch of chubs per lift of 10,000 linear feet of gill nets in Illinois (table 13) ranged from 445 in 1951 to 583 in 1953. Without exception these averages were higher than those of the adjacent Michigan district, M-8 (table 9). The 1953 catch per lift was also greater than that for the Wisconsin district immediately to the north.

The Wisconsin and Michigan records of catch per lift in 1953 are believed to be comparable as measures of the availability of chubs. The minimum legal mesh size was 2-1/2 inches in both states and both had reasonably effective enforcement of the law. Wisconsin and Michigan regulations did differ as to maximum legal depth (distance from float line to lead line) of chub gill nets. In Wisconsin these nets could not be more than 35 meshes deep whereas in Michigan the maximum legal depth was 11 feet. Despite this difference in the regulations, the nets actually fished by Wisconsin and Michigan fishermen were approximately the same. Operational disadvantages of deep gill nets prevented Michigan fishermen from taking advantage of their more liberal regulation. The relatively high catch per lift in Illinois probably does not reflect a higher abundance of chubs but resulted from the small mesh size of nets fished by Illinois fishermen.

If allowance is made for the small mesh fished in Illinois, and if the detached waters of Green Bay and districts M-3 and M-4 are excluded, it may be stated that the availability of chubs varied only moderately in 1953 among different areas of the main basins of Lake Michigan. Major difference between districts in which similar nets were fished was provided by W-4 (354 pounds per unit effort) and W-6 (506 pounds). The unweighted mean of the catch per lift in Wisconsin districts W-3 through W-6 was 429 pounds. In Michigan the corresponding figure for M-2 and M-5 through M-8 was 427 pounds. The situation in 1953 contrasts sharply with that in 1930-1932 when results of experimental fishing led Van Oosten (1933) to state that, "Chubs were found to be about 2.7 times as abundant in the Michigan waters of Lake Michigan as in the Wisconsin and Illinois waters of this lake." Van Oosten attributed the lower abundance of chubs in Illinois and Wisconsin to the more intensive fishing and the smaller meshes in the nets fished along the west shore. Although Van Oosten did not discuss production statistics, it can be seen from table 2 that the take was relatively light in Michigan in the years of the Fulmar operations. In 1930-1932 Wisconsin and Illinois catches were 6.2 times the Michigan catch. Strong support of Van Oosten's explanation

Table 13.--Production of chubs, intensity of the chub fishery, and catch of chubs per unit effort in the Illinois waters of Lake Michigan, 1950-1953

[Production in thousands of pounds; fishing effort in lifts of 10,000 linear feet of small-mesh gill nets, catch per unit effort in pounds]

Year	Production	Fishing effort	Catch per unit effort
1950	1,305	1/ 2,317	1/ 563
1951	822	1,848	445
1952	979	1,795	545
1953	1,188	2,036	583

1/ Estimated from data for the last 8 months of 1950; the catch per unit effort for the 8 months in 1950 was adjusted according to the ratio of the 8-mounth to the 12-month catch per unit effort in 1951-1953; this adjusted catch per lift was then divided into the 12-month 1950 catch to obtain an estimate of total fishing intensity

of the differences between abundance on the east and west shores in 1930-1932 can be drawn from the apparently similar abundance in 1953 after years of exploitation with the same kind of nets in Michigan and Wisconsin.

Intensity of the chub fishery in Lake Michigan, 1929-1953

State of Michigan, 1929-1953.--Statistics on the intensity of the chub fishery in the Michigan districts are presented in three forms.

First is the record of the number of units of 10,000 linear feet of small-mesh gill nets lifted that took chubs (table 14). This "effective fishing effort" excludes all or practically all small-mesh nets fished in shallow water for such species as lake herring, yellow perch (Perca flavescens), and round whitefish since chubs rarely enter the area in which those fisheries are carried on. The exclusion of lifts that took no chubs does not, on the other hand, bias the statistics by the omission of nets that were set on chub grounds but failed to make a catch. The distribution of chubs is such that nets fished at the proper depth always take some chubs. The records of table 14 have the further advantage that the nets were set exclusively for chubs--that is, without expectation of taking significant quantities of other species.

Because comments on fluctuations in fishing intensity and comparisons of districts are better made from later tabulations, the data of table 14 need be discussed only briefly. Most noteworthy information in the table, perhaps, is that on the actual magnitude of the fishery. The intensity unit of 10,000 feet corresponds to the lifting of 1.894 miles of gill nets. With this factor some more meaningful figures can be computed. It is seen, for example, that within individual districts the total lifts for an entire year were sometimes extremely small--only 70 miles in M-2 in 1943 and but 76 miles in M-8 in 1929. Other total annual lifts were large--3,941 miles in M-3 in 1938 and 4,591 miles in M-8 in 1953. For the combined districts the total length of chub gill nets lifted ranged from 2,752 miles in 1944 to 16,196 miles in 1953. The average number of miles of chub gill nets lifted per year in the 7 districts was 6,905 in 1929-1943 and 10,280 in 1944-1953.

The second set of statistics on fishing intensity (table 15; figs. 3-9) concerns the percentage fluctuations of fishing pressure in the individual districts about the 1929-1943 mean. The indices of table 15 are closely similar to the figures that would be obtained if percentage fluctuations were computed from the records for small-mesh gill nets in table 14 but are not identical since adjustments were made to take account of the small catches of chubs from gears other than small-mesh gill nets. This adjustment is made easily by expressing fishing intensity as an "expected catch" in pounds of fish. The procedure is illustrated by the following file records for district M-7 in 1947.

Production (pounds)	
In small-mesh gill nets . . .	418,316
In other gear (large-mesh gill nets)	5,513
Total	423,829
Gill-net units lifted (small mesh)	1,225.9
Catch (pounds) per unit in 1947 (418,316/1,225.9). . .	341.2
Catch (pounds) per unit, 1929-1943 average . .	186.7
Abundance index (341.2/186.7 x 100)	182.8
Expected catch (423,829/ 1.828)	231,858

The "expected catch" is merely the pounds of chubs that would have been caught by the amount of fishing done in M-7 in 1947 if the abundance of chubs had been exactly at the 1929-1943 mean of 100.0 rather than 182.8 percent of average. In making this computation it is assumed that chubs captured in chub gill nets and in other gears experience the same fluctuations of availability. The expected catches computed for each year by this procedure were the statistics from which the intensity indices of table 15 were calculated.

The intensity of the chub fishery varied widely in all statistical districts (table 16). The ratio of the maximum to the minimum intensity ranged from 8.9 in M-7 to 62.9 in M-8. The greatest fishing pressure was exerted in 1935 in 3 districts (M-4, M-5, M-6), in 1938 in 1 (M-3),

Table 14.--Number of units of 10,000 linear feet of small-mesh gill nets lifted in the chub fishery in the statistical districts of the State of Michigan waters of Lake Michigan, 1929-1953

Year	District							Total
	M-2	M-3	M-4	M-5	M-6	M-7	M-8	
1929	261	725	394	817	144	853	40	3,234
1930	193	856	396	536	61	847	340	3,229
1931	142	469	254	273	78	716	302	2,234
1932	79	208	268	228	248	487	217	1,735
1933	140	230	263	182	225	445	130	1,615
1934	252	889	441	345	593	622	490	3,632
1935	565	1,444	614	1,761	1,365	1,069	537	7,355
1936	846	1,604	505	1,653	1,066	1,122	813	7,609
1937	449	1,533	226	1,204	1,059	926	259	5,656
1938	339	2,081	136	1,429	1,229	1,091	652	6,957
1939	189	950	104	1,146	871	1,042	618	4,920
1940	108	203	181	398	111	357	133	1,491
1941	115	414	194	573	101	225	112	1,734
1942	90	490	173	336	301	199	217	1,806
1943	37	179	108	168	143	475	377	1,487
Average 1929-1943	254	818	284	737	506	698	349	3,646
1944	107	367	179	283	29	394	94	1,453
1945	510	486	226	702	238	534	71	2,767
1946	812	152	143	345	409	703	222	2,786
1947	466	261	312	548	749	1,226	626	4,188
1948	857	146	267	1,065	1,034	1,544	1,539	6,452
1949	1,207	610	321	1,143	1,129	1,491	1,703	7,604
1950	1,141	441	200	991	1,133	1,344	1,258	6,508
1951	1,584	511	54	935	928	1,361	1,328	6,701
1952	1,507	410	188	924	948	1,447	1,842	7,266
1953	1,781	569	261	884	830	1,802	2,424	8,551
Average 1944-1953	997	395	215	782	743	1,185	1,111	5,428

Table 15.--Fluctuation of the intensity of the fishery for chubs in the statistical districts of the State of Michigan waters of Lake Michigan

[Expressed as percentages of the 1929-1943 average]

Year	District						
	M-2	M-3	M-4	M-5	M-6	M-7	M-8
1929	101	89	138	110	29	122	11
1930	78	106	140	74	13	122	98
1931	58	58	90	38	15	103	87
1932	31	26	95	34	49	71	64
1933	56	28	92	26	45	63	37
1934	98	108	155	58	116	88	140
1935	219	176	216	233	266	158	154
1936	329	196	177	218	208	160	233
1937	178	186	79	160	206	133	74
1938	135	253	48	191	240	154	186
1939	74	116	37	152	171	147	176
1940	43	25	65	55	25	51	38
1941	46	51	69	80	22	32	32
1942	37	60	61	47	62	29	62
1943	17	22	38	24	33	67	108
1944	43	46	64	39	18	57	28
1945	203	60	80	93	62	79	21
1946	315	19	50	46	85	103	64
1947	181	33	109	72	145	175	180
1948	332	18	94	141	200	220	440
1949	467	74	113	151	218	211	486
1950	442	54	70	130	219	190	359
1951	614	62	19	123	179	191	379
1952	583	50	66	121	183	204	526
1953	689	69	92	116	161	254	692

Table 16.--Value and year of lowest and highest indices of fishing intensity for chubs in the statistical districts of the State of Michigan waters of Lake Michigan, 1929-1953, and ratios of the extreme values

District	Minimum intensity		Maximum intensity		Ratio of indices
	Index	Year	Index	Year	
M-2	17	1943	689	1953	40.5
M-3	18	1948	253	1938	14.1
M-4	19	1951	216	1935	11.4
M-5	26	1933	233	1935	9.0
M-6	13	1930	266	1935	20.5
M-7	29	1942	254	1953	8.9
M-8	11	1929	692	1953	62.9
All 1/	41	(1943 (1944	240	1953	5.9

1/ From Table 17; the figures include an adjustment for fishing operations in District M-1

and in 1953 in 3 (M-2, M-7, M-8). Years of minimum intensity ranged from 1929 in M-8 to 1951 in M-4. For the combined districts the maximum intensity of 240 in 1953 was 5.9 times the minimum of 41 in 1943 and 1944 (data from table 17).

Despite certain disagreements and exceptions to trend, the fluctuations of fishing intensity in the various districts exhibited numerous similarities. The trend was downward during the earlier years of the 1929-1953 period, and in both 1932 and 1933 intensity was below the 1929-1943 average (usually by a wide margin) in every district. Fishing intensity increased in every district in 1934. It was above the 15-year average in all 7 districts in 1935 and 1936 and in 5 or 6 districts in 1937-1939. A general decline dropped intensity indices of all districts below the 1929-1943 average in 1940 and with only 4 exceptions (M-8 in 1943; M-2 in 1945 and 1946; M-7 in 1946) they remained below average through 1946. The next 7 years (1947-1953) were a period of generally intensive fishing in all districts but M-3 and M-4. The index did not reach the 15-year average in M-3 (highest value, 74 in 1949) and in M-4 it was below average in all years but 1947 and 1949. In the remaining districts only one index was below average (M-5 in 1947) and some extremely high levels were reached, especially in M-2 and M-8.

The third presentation, based on records of the expected catch, indicates fluctuations within districts and also permits comparisons between districts (table 17). The unit in the table is an expected catch of 7,620 pounds or 1/1.500 of the total expected catch of all 8 districts over the 15-year base period 1929-1943. (The expected catch in M-1 each year was estimated by dividing 1/100 of the average abundance in districts M-2 through M-8 into the actual production of M-1.) As a result of this arrangement, the sum of the units for the districts in a particular year provides an index of fishing intensity in all State of Michigan waters, expressed as a percentage of the 15-year average. Furthermore, the 1929-1943 average number of units for a single district is an estimate of the percentage of the 15-year total intensity exerted in the district. A peculiar feature of this method of estimating intensity is the variation among the districts in the amount of fishing pressure represented by a unit of gear. The lift of 10,000 feet of chub gill nets, represents an expected catch equal to the 15-year average catch-per-unit-effort in the district in which the gear is lifted. As may be seen in table 9 this figure ranged from 184 pounds in M-4 to 253 pounds in M-2.

Since the fluctuations of fishing intensity within individual districts were described from tables 15 and 16, comments on table 17 are concerned principally with between-district comparisons. Fishing pressure was invariably lightest in M-1, the district in which chub fishing is so unimportant that records of gear are not maintained. Some of the remaining 7 districts tended to have relatively intensive and others light fishing, but for all of them the annual ranking varied widely (table 18). In 1929-1943, the range of the ranks covered 5 or 6 positions in every district but M-2 (range of 4--fourth to seventh). The 3 districts that shared first rank, for example, also ranked as low as fifth (M-5, M-7) or sixth (M-3). Similarly the 4 districts which at some time held last position were in other years as high as fourth (M-2), third (M-4) or even second (M-6, M-8). Variations were wide in 1944-1953 also. M-8, for example, had a more intensive chub fishery than any other district in 4 of the 10 years, but in 2 years was in last place. The ranges were smaller in the remaining districts but were never less than 4 positions (M-4, M-7).

The distribution of fishing intensity among the districts changed notably from 1929-1943 to 1944-1953. In the 15-year base period, fishing intensity, on the average, was heaviest in M-3 (20.7 percent of total) and M-5 (20.6 percent) followed by M-7 (17.4 percent) and M-6 (15.9 percent). The remaining three districts were all under 10 percent. In 1944-1953 the centers of most intensive fishing had shifted to M-2 and M-8. The former district accounted for 21.6 percent of the 1944-1953 intensity and was in first position as contrasted to sixth in 1929-1943. At the same time M-8 increased its percentage from 9.6 to 19.8 and its rank from fifth to second. Greatest decrease occurred in M-3 which dropped from first to sixth position and suffered a percentage loss from 20.7 to 6.5. The relative

Table 17.--Intensity of the fishery for chubs in the State of Michigan waters of Lake Michigan, 1929-1953

(The unit is 1/1.500 of the total expected catch for all districts over the 15-year period, 1929-1943)

Year	District								Total
	M-1	M-2	M-3	M-4	M-5	M-6	M-7	M-8	
1929	0.8	8.7	18.4	9.5	22.7	4.7	21.2	1.1	87.1
1930	0.2	6.7	21.9	9.7	15.2	2.0	21.1	9.3	86.1
1931	0.8	5.0	11.9	6.2	7.9	2.4	17.9	8.3	60.4
1932	0.3	2.6	5.3	6.5	6.9	7.8	12.3	6.1	47.8
1933	0.0	4.8	5.9	6.4	5.3	7.1	11.0	3.6	44.1
1934	0.0	8.4	22.4	10.6	11.9	18.4	15.4	13.4	100.5
1935	0.0	18.8	36.4	14.9	48.1	42.2	27.4	14.8	202.6
1936	0.2	28.2	40.5	12.2	45.0	33.2	27.7	22.3	209.3
1937	0.0	15.2	38.6	5.5	32.9	32.9	23.1	7.1	155.3
1938	0.7	11.6	52.4	3.3	39.3	38.1	26.8	17.9	190.1
1939	0.6	6.3	24.0	2.5	31.4	27.2	25.6	16.9	134.5
1940	0.3	3.7	5.2	4.4	11.4	3.9	8.8	3.7	41.4
1941	1.1	3.9	10.5	4.7	16.5	3.5	5.5	3.1	48.8
1942	0.6	3.1	12.4	4.2	9.7	9.8	5.0	6.0	50.8
1943	0.2	1.5	4.6	2.6	5.0	5.3	11.7	10.3	41.2
Average 1929-1943	0.3	8.6	20.7	6.9	20.6	15.9	17.4	9.6	100.0
1944	0.2	3.7	9.5	4.4	8.1	2.8	9.9	2.6	41.2
1945	0.7	17.4	12.5	5.5	19.2	9.8	13.7	2.0	80.8
1946	0.0	27.0	4.0	3.5	9.5	13.5	17.9	6.2	81.6
1947	0.0	15.5	6.7	7.5	14.9	23.1	30.4	17.3	115.4
1948	0.7	28.5	3.7	6.4	29.0	31.8	38.2	42.2	180.5
1949	0.3	40.0	15.3	7.7	31.1	34.7	36.6	46.6	212.3
1950	1.9	37.8	11.1	4.8	26.8	34.8	32.9	34.4	184.5
1951	0.8	52.6	12.8	1.3	25.3	28.5	33.3	36.3	190.9
1952	1.0	49.9	10.3	4.5	25.0	29.1	35.5	50.4	205.7
1953	0.6	59.0	14.3	6.3	23.9	25.5	44.2	66.3	240.1
Average 1944-1953	0.6	33.1	10.0	5.2	21.3	23.4	29.3	30.4	153.3
Percentage	0.4	21.6	6.5	3.4	13.9	15.3	19.1	19.8	...

Table 18.--Distribution of rankings and mean rankings of the State of Michigan districts of Lake Michigan with respect to the intensity of the chub fishery, 1929-1943 and 1944-1953

[The percentages of total fishing intensity in each district are from table 17]

Rank	District						
	M-2	M-3	M-4	M-5	M-6	M-7	M-8
1929-1943							
1	...	5	...	6	...	4	...
2	...	3	...	1 1/2	6 1/2	3	1
3	...	3	1	3 1/2	3 1/2	3	1
4	1	2	5	2	...	3	2
5	4	1	1	2	1	2	4
6	5 1/2	1	4	...	2	...	2 1/2
7	4 1/2	...	4	...	2	...	4 1/2
Percentage	8.6	20.7	6.9	20.6	15.9	17.4	9.6
Rank	6	1	7	2	4	3	5
1944-1953							
1	3	...	...	1	...	2	4
2	4	1	...	...	2	2	1
3	...	...	...	1	2	5	2
4	1	1	1	2	4	1	...
5	2	...	...	6	1	...	1
6	...	6	3	...	1	...	...
7	...	2	6	...	...	...	2
Percentage	21.6	6.5	3.4	13.9	15.3	19.1	19.8
Rank	1	6	7	5	4	3	2

importance of M-5 also decreased substantially from second to fifth in rank and from 20.6 to 13.9 in percentage. The percentage decreased sharply--from 6.9 to 3.4--in M-4 but that small district held last place in both periods. M-6 and M-7 did not change ranking and experienced small changes of percentages.

The average annual number of intensity units was higher in 1944-1953 than in 1929-1943 in every district but M-3 and M-4. The greatest increases were in M-2 (1944-1953 average of 33.1 units, 3.85 times the 1929-1943 mean of 8.6) and M-8 (1944-1953 average of 30.4 units, 3.17 times the 1929-1943 figure of 9.6). In the remaining districts the ratios of 1944-1953 to 1929-1943 intensity were: M-7, 1.68; M-6, 1.47; M-5, 1.03; M-4, 0.75; M-3, 0.48.

The intensity indices for the combined districts (right-hand column of table 17; fig.10) show alternating periods of above- and below-average fishing pressure. The index was 87 (actually 87.1) in 1929, from which point it dropped to only 44 in 1933. Fishing pressure more than doubled in 1934 and again in 1935 to reach an index value of 203 in the latter year. The index was even higher in 1936 (209) and continued well above 100 through 1939. The drop to 41 in 1940 ushered in a 5-year period in which the intensity index exceeded 50 only once (1942) and a 7-year interval of values below 100. The increase that started in 1945 carried the index past the 15-year base value in 1947 (115). Intensity was consistently high--from 180 to 240--in 1948-1953.

Previous inquiries into factors controlling fishing intensity in the Great Lakes (Van Oosten, Hile, and Jobes, 1946; Hile, 1949; Hile, Eschmeyer, and Lunger, 1951a, b; Hile, Lunger, and Buettner, 1953) have shown the problem to be extremely complicated. Although a listing of the major factors would be simple, it is difficult to obtain information on some (particularly the economics of the fisheries), and their interactions and effects are so varied that analyses seldom lead to conclusive results.

The fluctuations of fishing intensity for chubs in Lake Michigan are better understood in the light of their relation to those of other fisheries. Most chub fishermen have traditionally directed nearly all of their fishing activity toward the capture of lake trout and chubs. As the lake trout fishery declined and disappeared during the 1940's the fishermen turned more and more to chub fishing, and finally most became entirely dependent on chubs. The disappearance of lake trout offers a simple explanation of the recent upward trend and of the generally high level of fishing intensity for chubs beginning about 1948. The only two districts that had lower fishing intensity in 1944-1953 than in 1929-1943 (M-3 and M-4) also experienced such poor chub fishing in recent years (in comparison with other districts) that some fishermen either reduced or abandoned fishing operations, and others moved to better grounds.

Although the recent high fishing intensity for chubs can be explained easily as the result of the decline of the lake trout, no similar general explanation can be offered for fluctuations in 1929-1943 before either the decline of trout or the introduction of the more efficient nylon netting (table 19). High availability of chubs might be expected to stimulate fishing intensity and low availability to depress it; a significant positive correlation (5-percent level) occurred, however, in only 2 districts (M-4 and M-5). Since chubs were the principal alternative species to the lake trout and since fishing for chubs and trout are almost mutually exclusive (few chubs are caught in trout nets and few legal-sized trout in chub nets) fishing intensity for chubs should be correlated negatively with the abundance of trout and with the intensity of the lake trout fishery. A significant negative correlation between the abundance of trout and fishing intensity for chubs occurred in only 1 of 7 districts (M-7, $r = -0.795$, $p < 0.01$); apparently the fluctuations in availability of trout were not sufficient to produce the expected relationship. Fishing intensities for lake trout and for chubs were correlated at the 5-percent level in M-2 and M-4 and at the 1-percent level in M-6, but not in the other 4 districts. The additional data of table 19 on correlations between the abundance of chubs and of lake trout and between fishing intensity for trout and the abundance of that species give no reason to question the conclusion that factors controlling fishing intensity for chubs in 1929-1943 were complex and variable.

Table 19.--Correlations (r) for 1929-1943 fluctuations of certain items in the chub and lake trout fisheries of the State of Michigan waters of Lake Michigan

[Absolute values of r corresponding to 1-, 5-, and 10-percent levels of probability are 0.641, 0.514, and 0.441]

Items correlated	District						
	M-2	M-3	M-4	M-5	M-6	M-7	M-8
Abundance, chubs; fishing intensity, chubs	0.197	0.399	0.543	0.537	-0.350	-0.156	0.111
Abundance, lake trout; fishing intensity, chubs	0.416	-0.215	0.095	-0.116	-0.206	-0.795	-0.158
Fishing intensity, lake trout; fishing intensity, chubs	-0.552	0.108	-0.563	0.107	-0.747	-0.250	0.065
Abundance, chubs; abundance, lake trout 1/	0.126	-0.171	-0.002	-0.273	0.449	0.107	0.648
Abundance, lake trout; fishing intensity, lake trout 2/	0.034	-0.378	-0.677	-0.379	0.225	0.357	0.633

1/ From Table 12

2/ From Hile, Eschmeyer, and Lunger (1951); these correlations are for 1929-1941

States of Illinois, 1950-1953, and Wisconsin, 1953.--Because of the limited number of years of record, statistics on fishing intensity in Illinois and Wisconsin are given only in terms of the number of lifts of 10,000-foot units of gill nets. The lifts in Illinois (table 13) ranged from 1,795 in 1952 to an estimated (see footnote to table) 2,317 in 1950. Fishing intensity was greater in Illinois in 1950 and 1951 than in the larger adjacent Michigan district M-8 (table 14), but was less in 1952 and 1953. The 1953 intensity of 2,036 units in Illinois was 1.74 times that in the small Wisconsin district, W-6, immediately to the north (table 7--see also fig. 2).

The 1953 fishing intensity in Wisconsin districts W-1 and W-2 was inconsequential but pressure was heavy in districts W-3 through W-6, especially in W-4 and W-5 where the numbers of units lifted were 5,093 and 5,323, respectively. How greatly the fishing pressure on the west side of Lake Michigan exceeded that on the east is brought out by the following tabulation of the numbers of units of small-mesh gill nets lifted (Green Bay districts omitted):

West shore	Units	Miles
Wisconsin, W-3 through W-6	15,366	29,103
Illinois	2,036	3,856
	17,402	32,959
East shore		
Michigan, M-2 through M-8	8,551	16,196

The production records of earlier years (table 2) suggest that in the past as well as in 1953, fishing intensity was much the greater on the western side of Lake Michigan.

Summary

The chub fishery of Lake Michigan has been based on 7 species of the subgenus Leucichthys of the genus Coregonus. The species composition of the catch has exhibited long-term trends and also varies seasonally. Largely because of inadequate taxonomy and local variation of common names, part or all of the earlier production of chubs was combined in the statistics with catches of such other species as whitefish and lake herring. Usable statistics of production begin with 1926. Figures for earlier years serve principally to show that an active fishery for chubs existed back into the 1890's and that the take in some years ran to several million pounds.

The catch of chubs in Lake Michigan (4 states combined) in 1926-1953 ranged from 1,630,000 pounds in 1941 to 11,151,000 pounds in 1953. The production increased annually over the 1941-1953 period. The 1926-1953 average was 5,135,000 pounds. Of this amount Wisconsin contributed 60.3 percent; Michigan, 24.8 percent; Illinois, 12.7 percent; and Indiana, 2.2 percent. Catches listed for Indiana were made mostly or entirely in State of Michigan waters.

Records of catch are available for the 8 statistical districts (M-1 through M-8--see fig. 2 for boundaries of districts) of the State of Michigan in 1929-1953. The production of chubs has always been insignificant in M-1 (Green Bay). The annual take varied widely in the remaining 7 districts but it exceeded 400,000 pounds in at least one year in each of them but the small district M-4. Centers of major production shifted from 1929-1943 to 1944-1953. In the former period the only districts that contributed more than 20 percent of the total catch were M-3 and M-5. In 1944-1953 the catch amounted to 20 percent or more of the total in M-2, M-7, and M-8.

Records of chub production in Wisconsin districts (W-1 through W-6) are at hand for 1953 only. (Reports back through 1936 remain to be analyzed.) Here as in Michigan the Green Bay catch (W-1 and W-2) was unimportant but the take was heavy in the main-lake districts--from 592,000 pounds in the relatively small district W-6 to 2,235,000 pounds in W-5. Illinois and Indiana waters are not divided into statistical districts.

The use of data on catch per unit effort to estimate fluctuations in the abundance or availability of chubs is handicapped by bias from the following sources: changes in the regulations on the minimum legal mesh size of small-mesh gill nets (the principal gear of capture of chubs); variation in the enforcement of the laws; changes in the efficiency of twine from which the nets are constructed. Possible effects of these factors are discussed and records of fluctuations in abundance

are presented with the understanding that they are the best that can be offered from the data at hand.

The abundance index (annual catch per unit effort expressed as a percentage of the average for the 1929-1943 base period) fluctuated widely in all 7 important chub-producing districts (M-2 through M-8) of State of Michigan waters in 1929-1953. The ratio of the highest to the lowest index value ranged from 2.1 in M-3 to 5.2 in M-8. The lowest index in any district in any year was 56 in M-7 in 1937 and the highest was 299 in M-8 in 1944. Coefficients of correlation between abundance indices of different districts in 1929-1943 gave evidence of some similarities of fluctuations but did not indicate lake-wide correlation. Neither could a consistent relationship be established over the same 15-year period between fluctuations in the abundance of chubs and of lake trout (which prey on chubs) or of the related lake whitefish and lake herring. Similar studies were not undertaken for 1944-1953 because of the disturbing effects of the disappearance of the predatory lake trout on the abundance of chubs and the introduction of nylon nets on the estimation of that abundance.

For the combined State of Michigan districts the fluctuations in the abundance index of chubs have been irregularly cyclic. The abundance index stood at 121 in 1929, dropped to 90 in 1932, rose to 127 in 1934, decreased (with one exception to trend) to the 25-year low of 78 in 1940, climbed to 182 in 1945, fell to 136 in 1949, increased to the 25-year high of 200 in 1952, and was 180 in 1953. Contributing to the recent high values of the index (from 136 to 200 in 1944-1953) have been the disappearance of the lake trout and (during the last 5 or 6 years) the introduction of nylon twine.

Records of catch per unit effort are available for 1950-1953 in Illinois and for 1953 only in Wisconsin. The catch of chubs per 10,000 linear feet of gill net in Illinois ranged from 445 pounds in 1951 to 583 pounds in 1953. The 1953 figure in Wisconsin districts W-3 to W-6 was from 354 in W-4 to 506 in W-6. The average catch per unit effort in the "main-basin" districts of Michigan (M-2 and M-5 through M-8) in the same year was from 415 pounds in M-5 to 447 in M-8. If some allowance is made for the smaller mesh fished in Illinois, it appears that the abundance of chubs in 1953 was generally similar throughout the principal basins of Lake Michigan. At the time of the 1930-1932 survey of the Bureau of Fisheries vessel Fulmar chubs were 2.7 times more plentiful along the east (Michigan) shore than along the west (Illinois-Wisconsin) shore.

The intensity of the fishery for chubs in Michigan districts varied widely in 1929-1953; maximum fishing pressure in individual districts ranged from 8.9 (M-7) to 62.9 (M-8) times the minimum. Intensity was high in 1948-1953 (index figures from 116 to 692 in various districts and years) in extreme northern Lake Michigan (M-2) and in M-5 through M-8. In the same years, intensity was consistently below the 1929-1943 average in northeastern Lake Michigan (M-3) and exceeded that average only once in Grand Traverse Bay (M-4). Major centers of fishing in 1929-1943 were M-3 and M-5; in 1944-1953 fishing was heaviest in M-2 and M-8.

The intensity index for the combined districts was 87 in 1929, dropped to 44 in 1933, climbed to 209 in 1936, declined irregularly to the 25-year low of 41 in 1943 and 1944, increased to 212 in 1949, was 184 in 1950, and rose to the 25-year peak of 240 in 1953.

Although the principal factors that control the intensity of fishing can be listed with confidence, their interrelations are so complex and their effects so varied that it was not possible to establish clearly the influence of any one of them in the Michigan districts in 1929-1943. The more recent high fishing pressure can be attributed to the disappearance of lake trout which left the chubs as the major group of fish available to many fishermen.

The 1950-1953 fishing intensity for chubs in Illinois ranged from 1,795 10,000-foot units in 1952 to 2,317 in 1950. In 1953 the number of units in the principal chub-producing districts of Wisconsin (W-3 through W-6) ranged from 1,171 in W-6 to 5,323 in W-5. Fishing pressure was much greater in 1953 in Illinois and Wisconsin on the west shore than in Michigan along the east

and north shores. The total number of units lifted in Illinois and in Wisconsin districts W-3 through W-6 was 17,402 as compared with 8,551 in Michigan districts M-2 through M-8. The grand total of 25,953 units represents the lifting of more than 49,000 miles of chub gill nets.

The outlook for the Lake Michigan chub fishery is not bright. Three factors make for a progressive deterioration of stocks of salable fish: an increase in the intensity of the fishery against the larger chubs, brought about by the diversion of fishing pressure formerly directed against lake trout; the end of predation by trout and the consequent enormous increase in the abundance of the commercially valueless bloater; the selective destruction of the larger chubs by the still-plentiful sea lampreys. Of the three, destruction of larger chubs by lampreys seems likely in the long run to prove most damaging.

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Appendix

Lake Michigan chub fishery in 1954

As happens commonly with statistical reports, data for an additional year have become available since the preparation of the main manuscript. Tables 20 and 21 which contain the statistics for 1954 include also the data for 1953. Comparisons with years before 1953 may be made by consulting the tables of the main paper. The general trend from 1953 to 1954 was toward a small decrease of production, a slight rise in fishing pressure, and a modest decline in fishing quality. The direction and extent of changes varied among the several districts.

Production increased in 1954 in only one State of Michigan district (increase in M-3 from 133,000 pounds in 1953 to 155,000 pounds in 1954--table 20; boundaries of districts are shown in fig.2). The losses of the remaining districts ranged from a mere 3,000 pounds in M-6 to 254,000 pounds in M-2. For the combined districts the catch fell from 3,546,000 pounds in 1953 to 3,137,000 pounds in 1954--a decline of 409,000 pounds.

Table 20.--Comparison of chub fishery in Lake Michigan in 1953 and 1954

[Production in thousands of pounds]

Area	Production in all gears		Small-mesh nets lifted (10,000 foot unit)		Catch (pounds) per unit effort	
	1953	1954	1953	1954	1953	1954
Michigan						
M-1	9	1/ ...	...	...	...	...
M-2	759	505	1,781	1,500	426	337
M-3	133	155	569	633	234	244
M-4	67	63	261	223	256	282
M-5	367	352	884	881	415	400
M-6	338	335	830	860	407	390
M-7	790	702	1,802	1,696	439	414
M-8	1,083	1,025	2,424	2,763	447	371
Total	3,546	3,137	8,551	8,556	3/ 427	3/ 382
Wisconsin						
W-1	33	1	148	10	221	51
W-2	35	38	198	203	174	189
W-3	1,684	1,324	3,779	3,366	446	393
W-4	1,838	1,421	5,093	4,862	354	290
W-5	2,235	2,426	5,323	5,688	411	420
W-6	592	758	1,171	1,567	506	484
Total	6,417	5,967	2/ 15,366	2/ 15,483	4/ 429	4/ 397
Illinois	1,188	1,464	2,036	2,590	583	565
Grand total	11,151	10,568	2/ 25,953	2/ 26,629	...	...

1/ Less than 500
2/ Exclusive of Green Bay districts
3/ Main-lake districts--M-2, M-5 through M-8; unweighted mean
4/ Main-lake districts--W-3 through W-6; unweighted mean

Table 21.--Comparison of abundance of chubs and of the intensity of the chub fishery in State of Michigan waters of Lake Michigan in 1953 and 1954

District	Abundance index		Intensity index		Intensity unit	
	1953	1954	1953	1954	1953	1954
M-1	...	...	...	...	0.6	1/...
M-2	169	133	689	580	59.0	49.7
M-3	122	127	69	77	14.3	15.9
M-4	139	153	92	78	6.3	5.4
M-5	201	194	116	116	23.9	23.8
M-6	174	166	161	166	25.5	26.4
M-7	235	222	254	239	44.2	41.5
M-8	214	178	692	788	66.3	75.6
Total average	180	170	...	...	240.1	238.3

1/ Less than 0.05

The largest decreases of production in Wisconsin occurred in W-4 (drop of 417,000 pounds) and W-3 (decrease of 360,000 pounds). These decreases, together with the drop of 31,000 pounds in W-1 outweighed the increases of 3,000 pounds in W-2, 166,000 pounds in W-6, and 191,000 pounds in W-5 sufficiently to give a net loss of 450,000 pounds--from 6,417,000 in 1953 to 5,967,000 in 1954.

The take of chubs in Illinois increased 276,000 pounds--from 1,188,000 in 1953 to 1,464,000 in 1954.

In the entire lake (no catch reported for Indiana) the production of chubs decreased from 11,151,000 pounds in 1953 to 10,568,000 in 1954--a drop of 583,000 pounds.

Fishing pressure in State of Michigan waters (given in table 20 as units of small-mesh gill nets lifted and in table 21 as percentages of the 1929-1943 mean in individual districts--center of tables--and in the combined districts --right of table) decreased in 1954 in districts M-1 (table 21), M-2, M-4, M-5, and M-7 and increased in M-3, M-6, and M-8. The net change was small--an increase from 8,551 to 8,556 gill-net units in M-2 through M-8 and a decrease from an index figure of 240 to one of 238 in all districts. Two factors contributed to the disagreement between changes in number of units lifted and in the intensity index. First, the intensity index included an adjustment to cover fishing pressure represented by the chub fishery in district M-1. As is seen in table 21 this adjustment amounted to 0.6 unit in 1953 but was less than 0.05 in 1954. Second, under the procedure employed in determining these indices of fishing intensity the pressure represented by the lift of 10,000 feet of gill nets, though constant within a district, differs among districts. Thus the estimate of fishing intensity in combinations of districts depends both on the amount of gear lifted and on the distribution of the lifts among the districts. These points of method are treated in some detail in the section on fishing intensity.

Fishing pressure in Wisconsin declined in W-1, W-3, and W-4 and increased in W-2, W-5, and W-6. The main-lake districts showed a net increase of 117 units--from 15,366 in 1953 to 15,483 in 1954.

The number of gill-net units lifted in Illinois rose from 2,036 in 1953 to 2,590 in 1954--an increase of 554.

Fishing intensity for the entire lake, exclusive of Green Bay, increased from 25,953 units in 1953 to 26,629 in 1954--a rise of 676. Fishing pressure continued to be much heavier along the west than along the east and north shores. The 1954 total of 18,073 units (34,230 miles) of chub gill nets lifted in Wisconsin and Illinois was 2.11 times the figure of 8,556 units (16,205 miles) for State of Michigan waters. In 1953 the ratio was 2.04.

The quality of chub fishing in State of Michigan waters (catch per 10,000-foot lift in table 20; abundance indices in table 21) improved in M-3 and M-4 but declined in the remaining districts. The abundance index for the combined districts dropped from 180 in 1953 to 170 in 1954.

The catch per unit effort tended to decrease in Wisconsin also in 1954. The quality of fishing improved slightly in W-2 and W-5 but declined in the remaining districts. The average of 397 pounds per 10,000-foot lift in W-3 through W-6 was 15 above the mean of 382 pounds for the main-basin districts of Michigan (M-2 and M-5 through M-8).

The catch per unit effort in Illinois dropped from 583 in 1953 to 565 in 1954. The relatively high values, in comparison with Michigan and Wisconsin waters, in both years can be attributed to the smaller mesh fished in Illinois.

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